OCWP

2012

Oklahoma Comprehensive Water Plan

EXECUTIVE REPORT

The objective of the Oklahoma Comprehensive Water Plan is to ensure a dependable water supply for all Oklahomans through integrated and coordinated water resources planning by providing the information necessary for water providers, policy-makers, and end users to make informed decisions concerning the use and management of Oklahoma's water resources.

This study, managed and executed by the Oklahoma Water Resources Board under its authority to update the Oklahoma Comprehensive Water Plan, was funded jointly through monies generously provided by the Oklahoma State Legislature and the federal government through cooperative agreements with the U.S. Army Corps of Engineers and Bureau of Reclamation.

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Oklahoma Water Resources Board

February 2012

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The OWRB would also like to thank those agency employees primarily responsible for the development and organization of the *OCWP Executive Report* and thirteen Watershed Planning Region reports, particularly Kyle Arthur, Terri Sparks, Brian Vance, James Leewright, Darla Whitley, Owen Mills, and Mike Sughru. And finally, thanks to those individuals who reviewed, edited, created maps and charts, and wrote specific sections of the Executive and Regional Reports: J.D. Strong, Dean Couch, Jerry Barnett, Lou Klaver, Bob Sandbo, Monty Porter, Jason Childress, Chris Neel, Noël Osborn, Ryan Self, and Jon Phillips. Their work resulted in a serviceable and intelligible guide for Oklahoma's water future.

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J. D. STRONG
EXECUTIVE DIRECTOR

MARY FALLIN
GOVERNOR

STATE OF OKLAHOMA
WATER RESOURCES BOARD

The Honorable Mary Fallin, Governor

The Honorable Kris Steele, Speaker of the House
The Honorable Brian Bingman, President Pro Tempore of the Senate

Members of the Oklahoma Legislature

Citizens of Oklahoma

The Oklahoma Water Resources Board formally submits for your consideration this 2012 Update of the Oklahoma Comprehensive Water Plan (OCWP), the state's official long-range strategy for managing and protecting its invaluable surface and groundwater resources through at least the next 50 years.

Through unprecedented citizen input and expert technical analysis, the 2012 OCWP Update calls for progressive yet realistic strategies to ensure reliable water supplies for all Oklahomans. The exhaustive water data and sound policy advice contained herein provide essential information for the Governor, Legislature, water providers, and water users alike to make informed decisions concerning the use and management of Oklahoma's water resources. The OCWP provides a framework for assuring the fulfillment of both consumptive and non-consumptive uses of water. It challenges Oklahomans to think and act progressively through the implementation of sensible water conservation measures. It recognizes the need for renewed investments in our water and wastewater infrastructure and monitoring programs that provide, respectively, economic prosperity and foundational data for critically important water management decisions. And just as the OCWP was built upon unprecedented grassroots input, it solicits similar participation in its implementation by calling for the creation of formal regional planning groups to solve both existing and projected water problems at the local level.

While the 2012 OCWP Update establishes a landmark guide to address Oklahoma's immense and varied water challenges, its ultimate success will be determined by its implementation and measured by the degree to which all water needs are satisfied in the decades to come. To that end, the OWRB strongly encourages immediate administrative and legislative action, as appropriate and feasible, on the OCWP's priority recommendations, supporting policy initiatives and technical strategies.

In discharging its responsibility to plan for the development and protection of Oklahoma's waters, the OWRB adopted the 2012 OCWP Update on October 17, 2011. We strongly urge implementation of the 2012 OCWP Update and its recommendations to ensure dependable water supplies for all Oklahomans through the year 2060 and beyond, thus establishing a legacy for future generations.

Linda P. Lambert, Chairman — F. Ford Drummond, Vice Chairman — Joseph E. Taron, Secretary

Tom Buchanan — Ed Fite — Kenneth K. Knowles

Marilyn Feaver — Rudy Herrmann — Richard C. Sevenoaks

Foreword

A Vision for Oklahoma's Water Future

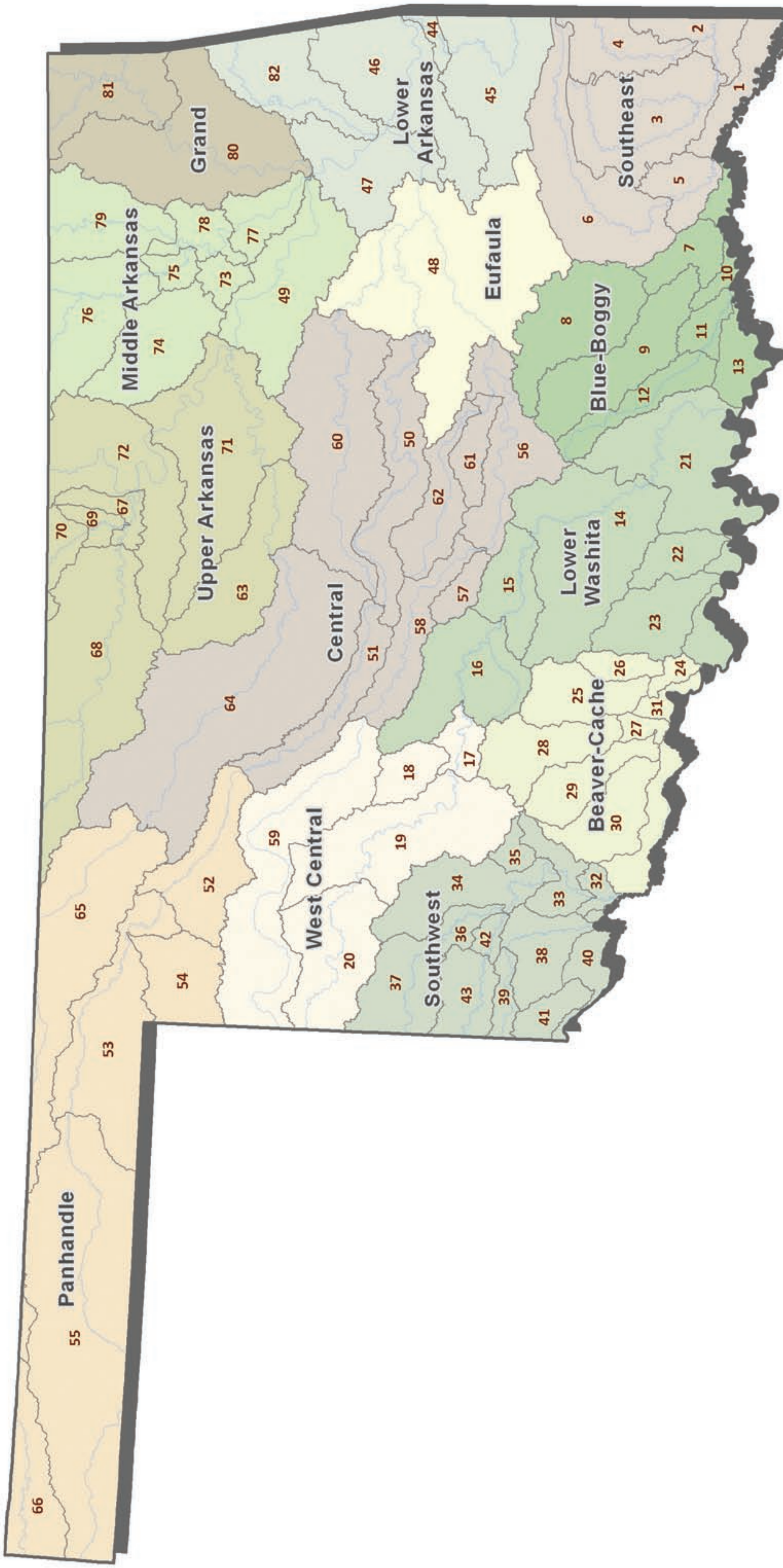
Recognizing Oklahoma's hydrologic, economic, and environmental diversity, past and current laws and programs that have resulted in successful development of the state's water resources, and the state's potential (as identified in the 2012 Update of the Oklahoma Comprehensive Water Plan*) to maximize both current and future development through aggressive water management and conservation strategies, the State of Oklahoma must be vigilant, proactive, inclusive, and bold in addressing and resolving circumstances that could threaten the reliability and utilization of water for all users and needs.*

Extensive public participation and detailed technical evaluations, the two pillars of this *2012 Update of the Oklahoma Comprehensive Water Plan*, have resulted in a bold, strategic vision with four core factors critical to securing Oklahoma's water future:

1. Infrastructure: Oklahoma must rise to the challenge of providing long-term, accessible funding—beyond what is currently available—to construct and maintain water and sewer systems that furnish safe, clean, and reliable water supplies for its citizens and communities. Failure to establish such funding for water and sewer projects threatens the state's future viability and growth, especially with respect to the state's smaller rural communities. Resolution of this looming problem demands the combined commitment and actions of citizens and elected officials, who must identify creative financing solutions and take advantage of regional infrastructure opportunities and shared sources of supply.
2. Data: Recognizing that information is the foundation for sound decision-making related to the development and protection of Oklahoma's water supplies, the State of Oklahoma must not only reestablish its dwindling base of reliable water data but expand the network of stream gages, monitoring wells, and water quality monitoring sites, as well as the tools necessary to quantify, manage, and allocate surface and groundwater resources confidently. In light of the anticipated stress on water supplies, unless the declining trend is reversed through the combined efforts of elected officials and the agencies and entities associated with managing and protecting Oklahoma's water, managers will lack the required information to justify extremely consequential and potentially costly decisions.
3. Management: While current water management programs have served the state well in developing, utilizing, and protecting water supplies, changing public priorities and additional stress on supplies suggest a more conservation-oriented approach in the future. The need for immediate changes to current policy has not yet been demonstrated, but it is clearly time to initiate proactive, systematic, and measured evaluation of existing water laws and procedures involving relevant agencies and appropriate stakeholders if we hope to maintain the stable and orderly utilization of water so critical to Oklahoma's economic welfare and quality of life.
4. Regional Planning: Integral to OCWP implementation is due recognition of local issues and priorities identified by citizens, users, and stakeholders. While statewide water planning has served Oklahoma well and oversight is still required at the state level, the time has come to encourage and formalize regional water planning as the new standard that empowers local citizens, who are more in touch with their unique needs, challenges, and potential solutions.

The compulsory strategy for accomplishing this vision is detailed in the OCWP's priority and supporting recommendations and their respective implementation plans.

Statewide OCWP Watershed Planning Region and Basin Delineation



Executive Summary

More than any other natural resource, water is crucially important for Oklahoma. Water unites us—and occasionally divides us—but undeniably provides an integral societal benefit. It supplies municipal and rural residents alike, and drives the state's vital agricultural industry. It is essential for oil and gas production, mining operations and other important industries. It is counted upon to generate power, sustain navigation, and support countless environmental and recreational uses. Without access to water, quality of life in Oklahoma would be threatened and the state's economy would cease to grow.

Although Oklahoma is blessed with an abundance of water, many citizens lack access to dependable sources due to distance to supplies, insufficient infrastructure or storage, water quality constraints, and other limiting factors. In many areas, surface water supplies are subject to seasonal fluctuations; supplies are frequently at their lowest when demand is the highest. The ability to store water in reservoirs—integral to surface water availability—can do much to mitigate the impacts of drought episodes and other water emergencies. Groundwater supplies, particularly bedrock aquifers, are less susceptible to seasonal fluctuations, yet concentrated demands or prolonged periods of decreased recharge can cause temporary reductions. Often, complex geologic factors impact a particular aquifer's ability to supply water; the amount of storage, depth-to-water, and well yields can vary significantly. In relatively shallow alluvial aquifers, the aquifer and overlying stream can be linked hydrologically, each resource impacting the other.

It was the recognition of these factors, combined with yet another devastating drought in 2006, that provided the impetus for development of the *2012 Update of the Oklahoma Comprehensive Water Plan (2012 OCWP Update)*. It is the most detailed and inclusive water planning effort in the state's history. While the initial 1980 OCWP and subsequent *1995 OCWP Update* were responsible for considerable improvements in how water supplies are managed, studied, and protected, the *2012 OCWP Update* takes planning to the next necessary level in its extensive analysis of Oklahoma's water past, present, and future.

Oklahoma citizens have been demanding and assuming more responsibility for their water supplies, which has naturally led to a significant increase in public interest for participation in state and local water resources decision-making. Recognizing the benefits of this shift in public awareness and involvment, the OWRB and its planning partners facilitated an unprecedented number of public and stakeholder input meetings during development of the *2012 Update*.

All factors impacting Oklahoma's water use for the next 50 years in each of the state's 82 planning basins were considered during OCWP water demand analysis. Impacts of forecasted demands on the physical availability of water supplies, including the amount, timing, and probability of potential shortages, were then predicted through 2060. Results indicate that in a number of planning basins, future consumptive demands will put a strain on water supplies, and may include surface water shortages (referred to as "gaps") and/or groundwater depletions (where use exceeds aquifer recharge). To address gaps and depletions, a number of options were evaluated for potential effectiveness.

Water quality, which varies considerably across the state, also has major implications for water users. Utilizing both current and historical data, including an analysis of water quality trends, surface water quality in all 82 basins was assessed. Increasing use, coupled with growth and development, will continue to pose water quality challenges, but OCWP information will provide enhanced confidence in the selection of future supply sources.

The availability of water for new permits is also an important consideration when evaluating the future impacts of increased demands. OCWP analyses indicated that a limited availability of unpermitted surface water will prevent some basins from meeting forecasted demands. Conversely, based on current permitting protocol, groundwater available for permitting is not a limiting factor in any planning basin despite a general decline in some aquifer levels. Several measures were also evaluated that could be implemented to improve the accuracy of water availability calculations and minimize future conflicts in the administration of water rights and permits.

According to OCWP analyses, providing reliable future water supplies to Oklahoma citizens will be seriously jeopardized without adequate funding to address the state's burgeoning infrastructure requirements. The absence of adequate and compliant drinking water and wastewater systems—even in the presence of abundant, high quality water—can limit economic growth and community development, impact water quality, threaten human health, increase future costs, and result in the waste and inefficient use of water. Future drinking water and wastewater infrastructure costs were evaluated as well as the financial investments and programmatic changes necessary to address the state's associated future need.

A number of other variables that might impact the ability of state water supplies to meet future demands were also analyzed. A changing climate could affect both supply and demand, significantly altering the way in which Oklahoma will use its water resources. The future timing, magnitude, and location of precipitation events could shift, directly affecting water availability, while temperature variations could impact demand patterns.

As a part of the water supply options analysis, opportunities to decrease demands through water conservation practices were assessed. Two scenarios were modeled to predict water savings associated with specific conservation measures in the state's largest water use sectors: Municipal/Industrial and Crop Irrigation. This analysis revealed promise in alleviating water shortages in most basins throughout the state, as well as the potential to make more water available for both consumptive and nonconsumptive uses, save energy, delay the need for new infrastructure, and decrease costs to citizens.

While conservation practices typically decrease demand or lead to more efficient use, a number of options exist to augment water supplies, where feasible, through largely unconventional measures. Two such options were evaluated: artificial aquifer recharge and marginal quality water use. Five sites were identified across the state where recharge demonstration projects could be most feasible. Concerning marginal sources, OCWP analyses determined that, in particular, treated effluent showed great promise for a number of uses and could provide supplemental sources of supply to alleviate future shortages.

To provide additional input and recommendations on particularly important water matters and related economic development concerns, stakeholder groups were commissioned specifically representing agricultural, climatological, and water quality interests to assess and prioritize future water research, monitoring, and policy requirements. These groups provided unique and invaluable expertise in identifying future state program and funding initiatives and priorities. A potential instream flow program for Oklahoma was investigated by a separate OCWP workgroup due to considerable interest from the public and a desire to ensure that future water management programs adequately balance utilization of the resource with environmental, social and economic benefits.

Overview of Technical Results and Findings

Coupled with policy recommendations, presented in detail in this report, the results of OCWP technical evaluations provide the foundation for detailed local and statewide implementation of water strategies and initiatives:

- Statewide, consumptive demand for water will increase by 33% between 2010 and 2060, not considering the potential decreases in demand that might stem from more aggressive water conservation measures.
- Crop Irrigation is forecasted to be the largest demand sector, consuming 897,464 acre-feet per year (AFY), or approximately 36% of the total demand. (One acre-foot equals 325,851 gallons.)
- Crop Irrigation will have the highest growth rate in the Panhandle, West Central, and Southwest OCWP Watershed Planning Regions.
- Thermoelectric Power will have the highest growth rate in the Upper Arkansas, Lower Arkansas, Southeast, and Blue-Boggy Regions.
- Municipal/Industrial will have the highest growth rate in the Middle Arkansas, Eufaula, Grand, Lower Washita, Beaver-Cache, and Central Regions.
- In 2060, Crop Irrigation will be the largest demand sector in the Panhandle, Southwest, West Central, and Blue-Boggy Regions.
- In 2060 Municipal/Industrial will be the largest demand sector in the Middle Arkansas, Eufaula, Grand, Lower Washita, Beaver-Cache, and Central Regions.
- In 2060 Thermoelectric Power will be the largest demand sector in the Upper Arkansas and Lower Arkansas Regions.
- In 2060 Self-Supplied Industrial will be the largest demand sector in the Southeast Region.
- The Oil and Gas demand sector will experience the highest growth rate statewide, approaching 200%, with pronounced growth in the Southwest, West Central, Panhandle, Upper Arkansas, and Lower Arkansas Regions. (However, the Oil and Gas sector will comprise only 5% of the 2060 demand.)
- The Panhandle Region will experience the highest 2060 water demand at 473,840 AFY. The Eufaula Region will have the lowest demand at 55,640 ac-ft/year.
- Generally, indoor water use (per capita) is highest in west and northwest Oklahoma, with a decreasing trend toward the east.
- Concerning the three recognized sources of water (surface water, alluvial groundwater, and bedrock groundwater) utilized in Oklahoma, bedrock groundwater is the primary source forecasted to supply 2060 demands in the Panhandle, Southwest, and Grand Regions. Alluvial groundwater will be the primary source in the West Central Region only. Surface water will be the primary supply source in all other regions.
- Surface water gaps, which occur when the demand for water is projected to exceed available supply, are forecasted in 55 of the 82 OCWP basins by 2060. The 10 most severe physical water availability constraints—considering degree and probability of occurrence—are forecasted in Basin 22 (Lower Arkansas); Basins 77 and 78 (Middle Arkansas); Basins 51 and 56 (Central); Basins 24 and 26 (Beaver-Cache); Basins 34 and 42 (Southwest); and Basin 63 (Upper Arkansas).
- Insufficient surface water permit availability to meet forecasted surface water demands in 2060 was forecasted in 22 basins. The 10 most severe permit availability constraints are forecasted in Basins 50 and 51 (Central); Basins 52, 53, 55, 65, and 66 (Panhandle); Basins 36 and 37 (Southwest); and Basin 20 (West Central).
- Based upon current trends and attainment of standards for beneficial uses, about one-third of the basins are considered to exhibit poor surface water quality and thus may face particular challenges in their ability to provide adequate and reliable supply. The 10 most water quality-challenged basins are in the Beaver-Cache, West Central, Middle Arkansas, Lower Washita, Southwest, and Upper Arkansas Regions.

- Considering overall surface water availability constraints—which is a collective assessment of physical, permit/legal, and water quality characteristics—the 10 basins projected to have the most severe limitations in meeting 2060 demands are Basin 51 (Central); Basins 34, 40, and 42 (Southwest); Basins 26 and 30 (Beaver-Cache); Basins 53, 65, and 66 (Panhandle); and Basin 22 (Lower Washita).
- Alluvial groundwater depletions, while generally minor, are forecasted to occur in 64 planning basins between now and 2060. Considering rates of depletion relative to the aquifer's total storage, the 10 basins projected to experience the most severe impacts are Basins 52 and 53 (Panhandle); Basins 34, 36, 38, and 42 (Southwest); Basin 47 (Lower Arkansas); Basins 51 and 56 (Central); and Basin 63 (Upper Arkansas).
- Bedrock groundwater depletions, though generally minor, were forecasted to occur in 34 basins. The Panhandle Region, which obtains 98% of its water supply from the Ogallala aquifer and is projected to have the largest water demand of any region in 2060, contains the top four basins forecasted to have the largest bedrock groundwater depletions. The 10 basins projected to experience the most significant bedrock groundwater depletions are Basins 53, 54, 55, and 66 (Panhandle); Basins 38, 40, and 41 (Southwest); and Basins 15, 22, and 23 (Lower Washita).
- Projected groundwater depletions are generally minimal compared to the total volume of water in aquifer storage. However, localized depletions may impact water quality, existing well production, and yields, or cause other adverse impacts to groundwater users.
- OCWP technical analyses identified 12 "Hot Spot" planning basins projected to have the greatest future water supply challenges: Basin 22 (Lower Washita); Basin 26 (Beaver-Cache); Basins 34, 36, 38, 40, 41, and 42 (Southwest); Basin 51 (Central); and Basins 54, 55, and 66 (Panhandle).
- Projections indicate that seven basins statewide have no future anticipated water shortages through 2060: Basin 2 (Southeast), Basin 7 (Blue-Boggy), Basin 27 (Beaver-Cache), Basin 35 (Southwest), Basin 70 (Upper Arkansas), Basin 81 (Grand), and Basin 82 (Lower Arkansas).
- Sufficient permit availability for groundwater use exists statewide. However, accessibility to groundwater supply could limit future localized use. (A characterization of groundwater quality was not a part of the assessment of potential limitations concerning future groundwater use due to the lack of comprehensive, long-term data. Such data will become even more important in light of future water demand forecasts indicating increased use and reliance on groundwater supplies.)
- An analysis of excess and surplus water determined that 52 basins have at least some amount of surplus water; 28 basins have none. No excess/surplus water exists in the Panhandle and West Central Regions. (This analysis was not conducted for the two basins in the Grand Region.)
- Even a moderate level of conservation could reduce surface water gaps statewide by 25% and reduce the number of basins with projected surface water gaps from 55 to 42, reduce alluvial groundwater depletions by 32% (64 basins reduced to 51), and reduce bedrock groundwater depletions by 15% (34 basins reduced to 26). In addition, this level of conservation could reduce statewide water consumption by 214,970 acre-feet/year by 2060. It would result in cost-savings of $47.5 million per year (2010 dollars) associated with reduced need for drinking water and wastewater treatment.
- Artificial recharge of groundwater is a viable option in augmenting supplies to meet future demands in several areas of the state. Five specific sites were considered particularly promising.
- The use of marginal quality water sources—such as brackish groundwater, treated wastewater effluent, production water from oil and gas operations, and stormwater runoff—have potential to augment supply in many areas of Oklahoma.
- Sixty-eight previously studied reservoir projects in Oklahoma are considered potentially viable sites for construction, depending upon local needs and the resolution of relevant economic, environmental, and other issues.
- Regional water conveyance systems have potential to increase water supply availability in several regions of the state, but the substantial expense of these systems will limit near-future implementation.
- Oklahoma could be considerably impacted by a changing climate—including reduced precipitation and higher temperatures—resulting in fundamental changes in water supplies, demand patterns, and availability.
- Oklahoma faces severe challenges related to financing water and wastewater infrastructure improvements. Almost $38 billion (in 2007 dollars) is required for drinking water and almost $43 billion (in 2010 dollars) for wastewater projects within the next 50 years. The Central Region will have the greatest water infrastructure need. This problem is particularly acute with smaller systems (those serving less than 3,000 people), which account for 46% of the future drinking water infrastructure need and 24% of the future wastewater need. Current state financing programs were determined to be inadequate to address the projected infrastructure crisis.

Policy Recommendations and Implementation

Implementable policy decisions must be backed by both sound science and broad public support. Recognizing this, the Oklahoma Water Resources Board (OWRB) commissioned the Oklahoma Water Resources Research Institute (OWRRI) in 2006 to design, oversee, and implement a vigorous and independent four-year public participation process for the *2012 OCWP Update*. From the outset, the OWRB had been focused foremost on an updated Water Plan that would be "FIT" (Fair—Inclusive—Transparent), and what resulted was an unprecedented level of openness, collaboration, and public involvement in statewide water planning, especially regarding water policy development.

The OWRRI's public participation process relied upon an iterative combination of policy analysis and deliberation (as prescribed by the National Research Council in 1996). To accomplish this, more than 100 local, regional, and statewide water planning meetings were held, engaging thousands of Oklahomans who volunteered both their time and unique perspectives. Collectively, more than 30,000 hours of volunteer time was invested.

The process began in 2007 with 42 local input meetings (LIMs) held throughout the state to solicit public opinion about issues that should be addressed by the *2012 OCWP Update*. In all, 2,300 citizens attended the LIMs and 2,500 comments from the public were collected, including issues for consideration, concerns about these issues, suggestions for their resolution, and further questions. These comments constituted the public deliberation agenda for what was to follow.

All LIM participants were invited to make nominations for participation in 11 regional input meetings (RIMs), held in 2008. From the nominations, the OWRRI identified 350 citizens to participate in the RIMs, assuring that all interests and geographic regions were represented. The principal task of the RIM participants was to prioritize the water policy issues that had been collected and consolidated from the LIMs. Each LIM issue was weighted according to its appropriateness and importance for consideration in the final *2012 OCWP Update*. Ten priority water issue themes were identified as a result.

To help prepare participants for the next stage of the planning process, the OWRRI and OWRB jointly held two separate one-and-one-half day seminars. These seminars informed RIM participants and other interested citizens on water resource management issues. The first of these addressed water policy, and the second, water science.

During the summer and fall of 2009, 30 planning workshops were convened in three consecutive sets for each of the ten issues identified in the RIMs. Workshops were held 10 weeks apart. Members were selected from among RIM participants based on their stated preferences for the issue groups in which they were interested. Participants in each session were balanced according to stated interests and geographic distribution. In all, 240 citizens took part.

Workshop participants were asked to formulate alternative water resource management strategies appropriate to their respective themes. Experts on relevant subjects attended each workshop group to answer questions specific to the theme. Between the first and second session, these experts evaluated potential strategies for their technical practicability, economic efficiency, administrative feasibility for implementation, political feasibility, and social acceptability. The reviews were presented to workshop participants at the beginning of the second workshop who then revised the alternatives and added more detail. These revised alternatives were again evaluated between the second and third workshops. Final revisions to strategy provisions were generated during the third workshop. Altogether, the workshops produced 54 provisional OCWP strategies organized into 11 categories for further discussion.

In 2010, the OWRRI contracted with the Oklahoma Academy for State Goals to host a statewide Town Hall meeting. Prior to the Town Hall, the OWRRI held a one-day water resource management strategy seminar to review workshop provisions, which helped participants better prepare for the meeting. Present at the Town Hall were 140 workshop participants and 32 additional Academy members with the goal to reach consensus on OCWP water policy recommendations. The Town Hall meeting was conducted in six simultaneous panels consisting of approximately 30 citizens each. Professional facilitators led a dialogue of all 11 discussion topics. Each panel included an official recorder. The three-day meeting yielded 55 total recommendations.

Following the conclusion of the Town Hall, the OWRB and OWRRI carefully analyzed the resulting Oklahoma Academy report, including both the Final Report and Recommendations sections, distilling that information with input and feedback received during the earlier public input process. The resulting draft recommendations—including those from workgroups, the OWRB, and other water management agencies—were presented for final public consideration at thirteen feedback and implementation meetings (FIMs) held in April and May, 2011. These meetings, which represented the final round of statewide public input on the draft *2012 OCWP Update*, were held in each of the 13 OCWP watershed planning regions.

Complementing the statewide input process, the OWRB also commissioned workgroups and specific state water management agencies to investigate and make recommendations on several unique or particularly sensitive policy and technical issues. Furthermore, the OWRB, as the state's water management agency, contributed its own recommendations to improve and enhance water use administration, water data for decision-making, infrastructure financing, and water-related research, and address legal issues of importance.

Prioritization is essential to the success of the OCWP and is required to focus limited resources on issues that require immediate attention. Also, certain recommendations received a higher degree of public support throughout the input process, including a final round of public feedback meetings held throughout the state in the spring of 2011. As a result, initial priority initiatives were selected based on: each recommendation's urgency in solving Oklahoma's most pressing near- and long-term water issues, the necessity of the recommendation in ensuring a reliable future water supply, recognition of the need to prioritize funding requests, findings of technical analyses, and input from OWRB staff with long-standing experience in water management. During regular meetings in June, July, August, and September, Water Board members deliberated the issues, consulted with staff, heard final comments from the public, and identified eight recommendations and implementation strategies deserving the utmost priority for implementation. These Priority Recommendations (including their implementation plans, where applicable) reflect the incorporation of a number of water policy initiatives from the public, water management agencies, and OCWP workgroups.

Supporting recommendations were also developed by OCWP public input participants, OCWP workgroups, partnering agencies, and OWRB staff. While they have not been included as Priority Recommendations, all are deemed prudent and necessary to the future use, management, and protection of Oklahoma's water resources. Similar to the Priority Recommendations, the OWRB will work diligently with appropriate state and federal agencies, stakeholders, and institutions to implement these water-related initiatives, and the OWRB encourages the State Legislature to recognize the importance of programs, policies, and funding needs addressed in each. Full workgroup reports summarizing their efforts are available on the OWRB website.

Priority Recommendations

Water Project & Infrastructure Funding	State/Tribal Water Consultation & Resolution
Regional Planning Groups	Water Conservation, Efficiency, Recycling & Reuse
Excess & Surplus Water	Water Supply Reliability
Instream/Environmental Flows	Water Quality & Quantity Monitoring

Supporting Recommendations & Initiatives

Nonpoint Source Pollution	Source Water Protection
Maximizing & Developing Reservoir Storage	Water Emergency/Drought Planning
Water Management & Administration	Water Supply Augmentation
Dam Safety & Floodplain Management	Water Related Research
Water Quality Management	Agricultural Water Research
Navigation	Climate & Weather Impacts on Water Management
Interstate Water Issues	

Priority Recommendations

Water Project & Infrastructure Financing

To address Oklahoma's considerable drinking water and wastewater infrastructure need and the inability of current programs to meet that need, the OWRB should coordinate with a team of infrastructure financing professionals to investigate development of a more robust state funding program to meet the state's projected water and wastewater infrastructure need between now and 2060. Any potential program(s) should include a specific mechanism to address the significant financing requirement of small communities in the state, as well as encourage regionalization of water/wastewater systems, where appropriate.

Addressing Oklahoma's Burgeoning Water and Wastewater Project Need

Over the next 50 years the need for both drinking water and wastewater infrastructure (including nonpoint source pollution control projects) in Oklahoma will be significant, projected to be almost $38 billion for drinking water and $44 billion for wastewater projects (based on 2007 and 2010 dollars, respectively). With most drinking water and wastewater infrastructure projects designed to last approximately 30 years, it is entirely possible that all such infrastructure across the state will have to be replaced completely at least once within the OCWP's 50-year planning horizon, let alone the needs for upgrades and improvements to meet increasingly stringent Federal standards and the demands of a growing population. Existing financing programs will lack the capacity to meet all—or even a significant portion—of that demand.

Drinking Water Infrastructure Need (in 2007 Dollars)*

Present to 2020	2021-2040	2041-2060	Total Period
$9,680,000,000	$10,610,000,000	$17,530,000,000	$37,790,000,000

**Over the next 10 years, based on current leveraging and subsidy levels, the average capital/equity investment reserve needed to meet 60% of the infrastructure demand is $185.6 million per year. From 2023 through 2040, no additional contributions are needed due to the revolving nature of the program. An additional $6.4 million is needed in years 2041 through 2060.*

Wastewater Infrastructure Need (in 2010 Dollars)**

Present to 2020	2021-2040	2041-2060	Total Period
$12,590,000,000	$22,830,000,000	$8,470,000,000	$43,890,000,000

***Over the next 10 years, based on current leveraging and subsidy levels, the average capital/equity investment reserve needed to meet 60% of the infrastructure demand is $290 million per year. From 2023 through 2040, an additional $44 million per year is needed. No additional reserve is necessary in 2041 through 2060 due to the revolving nature of the program.*

Regionalization of water supply providers generally refers to the consolidation of entities that share such things as a common water supply source, distribution infrastructure, treatment facilities and operation and maintenance. The opportunities for regionalization increase significantly when considering the many challenges facing smaller systems. This is especially true in rural areas and the proximity of small systems to large providers. Over half of the almost 800 primary public water supply systems analyzed for the *2012 OCWP Update* collectively serve less than 5% of the state's total population. Such small systems, primarily because of a small ratepayer base, lack the financial ability to meet increasingly stringent federal drinking water standards or to adequately maintain their systems. Benefits of regionalization can include reduced operating and maintenance costs, and in turn, reduced costs to ratepayers, more reliably maintained infrastructure, increased ability to meet regulatory standards, and greater access to affordable financing.

OCWP technical analyses indicate that regional supply sources, through an evaluation of the effectiveness of out-of-basin supplies and viable reservoir sites, will be an effective option to meet future demands in many basins. Additionally, it was recommended as a viable option for identified "hot spots." The extent to which regionalization should occur is largely a local decision dependent upon a variety of factors. Through the Drinking Water State Revolving Fund (DWSRF) loan program, the OWRB and Department of Environmental Quality have already begun to encourage consolidation and system cooperation through principal forgiveness incentives. However, a more comprehensive, aggressive, and well-funded program is required to encourage regionalization.

To ensure that publicly-owned water and wastewater systems have the financing opportunities necessary to secure clean and reliable water supplies for current and future generations, Oklahoma must consider at least the following options:

1. Maintain Gross Production Tax revenue for water and wastewater infrastructure.
2. Creation of a state-backed Credit Enhancement Reserve Fund (CERF).
3. Creation of a new or restructured Financial Assistance Program (FAP) Loan Program.
4. Creation of a small issuer loan initiative.
5. Encourage maintaining or increasing Federal SRF investments.
6. Consider the necessity of subsidy reduction and methodology.
7. Additional state investments.
8. Develop new methods to encourage regionalization of water and wastewater supply systems.

Implementation Plan

- Convene an advisory team of infrastructure financing professionals to investigate potential funding mechanisms to meet drinking water and wastewater project needs.
- Present recommendations from the advisory team to the OWRB for consideration within six months of convening.
- Present final recommendations to Oklahoma Legislature during the legislative session following OWRB approval, which could occur before the 2012 Legislature adjourns.

Regional Planning Groups

The OWRB should work with the State Legislature to develop and authorize the creation of at least thirteen Regional Planning Groups to assist in planning and implementing OCWP initiatives at the regional level. These regional groups should be non-regulatory and consist of local stakeholders, as well as appropriate agency representatives, charged with developing regional water plans in a manner consistent with the OCWP and its implementation priorities. Such plans would include the identification of specific projects, studies, programs, research, and other evaluations designed to address the unique needs and issues identified by Regional Planning Group participants. The State Legislature should establish regular appropriations to the OWRB to coordinate the activities of these groups.

Taking Statewide Water Planning to the Regional Level

There was widespread and strong support during the OCWP public input process for establishment of water planning and advisory groups organized according to the 13 OCWP Watershed Planning Regions. In addition to these regions, employed to facilitate data collection and technical analyses, communities and interest groups that rely upon the Arbuckle-Simpson (the state's only sole source aquifer) and Ogallala aquifers, which underlie multiple OCWP Watershed Planning Regions, are extremely interested in forming separate groups to better organize and unify their unique interests. Regional Planning Groups provide an opportunity for local stakeholders to guide planning initiatives (including the development of regional water plans), collaborate on issues of mutual interest, and provide associated local and regional input directly to the OWRB and other water management agencies. Such groups facilitate recognition of the specific issues and perspectives unique to each region of the state and could provide invaluable stakeholder input on many of the priority and supporting recommendations offered by the OCWP.

In contemplating the establishment of Regional Planning Groups, concerns often arise regarding the potential level of regulatory authority that could replace or usurp the role of state environmental agencies in managing water for the benefit of all Oklahoma citizens. Consistent with its statutory authority related to water management and planning, it is recommended that the OWRB maintain statewide oversight regarding the functions and activities of such groups.

Implementation Plan

1. Convene an advisory group of stakeholders (including water users and/or their representatives, state and federal agency staff, and the OWRB) to develop a detailed framework for the Regional Planning Groups, including the most appropriate delineation of geographical boundaries, membership, organization, duties and responsibilities, funding mechanism(s), and extent of authority.
2. At the earliest opportunity following the development of a consensus report by the advisory group, the OWRB will work with the Legislature to introduce legislation to create the Regional Planning Groups and to inform discussions regarding the passage of such legislation.
3. At the beginning of the first fiscal year (or as otherwise directed in the legislation) following legislative formation of the Regional Planning Groups, the OWRB will begin full implementation of the Regional Planning Groups as specified by the Legislature.

Costs

Based upon experiences of neighboring states, it is estimated that $95,100/year would be needed to coordinate Regional Planning Group meetings. Additional costs would be contingent upon the defined structure and duties of the groups.

Excess & Surplus Water

Pursuant to its statutory mandate found at 82 O.S. 1086.2(1), the OWRB adopts the following definition and procedure for determining excess and surplus water for inclusion in the OCWP update:

"Excess and surplus water" means the projected surface water available for new permits in 2060, less an in-basin reserve amount, for each of the 80 basins as set forth in the 2012 OCWP Watershed Planning Region Reports whose surface water is under OWRB jurisdiction (excepting the Grand Region); provided that nothing in this definition is intended to affect ownership rights to groundwater and that groundwater is not considered excess and surplus water.

The following procedure should be utilized to calculate excess and surplus water available for appropriation:

1. Each of the 80 OCWP watershed planning basins shall be considered an individual stream system wherein water originates (i.e., area of origin) for purposes of appropriation and permitting.
2. The total annual amount of available stream water for new permits in 2060 is equal to the total Surface Water Permit Availability amount as set forth in the OCWP Watershed Planning Region Reports minus the amount of the annual Anticipated Surface Water Permits in 2060 also set forth in those reports. The in-basin reserve amount is equal to 10% of the total Surface Water Permit Availability amount plus 10% of the annual Anticipated Surface Water Permits in 2060.
3. In considering applications for permits to transport and use more than 500 acre-feet of stream water per year outside the stream system wherein the water originates, the Board shall determine whether there is "unappropriated water available in the amount applied for" by considering only the remaining amount of excess and surplus water calculated for the stream system where the point of diversion is proposed, and for stream systems located downstream from this proposed point of diversion, provided this procedure shall not be used to reduce the amount authorized under existing permits and water rights.
4. The Board will also exclude from consideration for any permit for out-of-basin use:
   a. the quantity of water adjudicated or agreed by cooperative agreement or compact to be reserved for Federal or Tribal rights, and
   b. the quantity of water reserved for instream or recreational flow needs established pursuant to law.

Protecting Local Water Needs While Addressing Statewide Demands

Statutes require that the OCWP include a definition of "excess and surplus water of this state" and a recommended procedure for determining "excess and surplus water of this state… to ensure that the area of origin will never be made water deficient." This definition and procedure is especially critical as the OWRB addresses potential intrastate and interstate out-of-basin transfers of water. A transparent framework for defining and determining excess and surplus water is imperative when calculating water available for appropriation for use outside the basin of origin. The results of the comprehensive OCWP technical analyses form the basis of this definition and calculation.

Instream/Environmental Flows

The process developed by the OCWP Instream Flow Workgroup should be implemented and followed to ascertain the suitability and structure of an instream flow program for Oklahoma, with such process commencing in 2012 and concluding by 2015, as outlined by the Workgroup.

Recognizing Nonconsumptive Water Needs and Supporting Recreational and Local Economic Interests

Instream (or environmental) flows are those necessary to provide for a healthy ecosystem and support water-related recreation (such as fishing, hunting, swimming, and boating) as well as tourism. In 2006, 1.2 million residents and non-residents in Oklahoma participated in some form of fish and wildlife-related recreation—all directly or indirectly dependent upon water. These anglers, hunters, and wildlife viewers spent $1.3 billion in retail sales ($1.2 billion by residents and $125 million by nonresidents), creating $696 million in salaries and wages, and supporting 28,142 jobs. The total economic effect from fish and wildlife-related recreation was estimated at $2.3 billion. In 2008, Oklahoma's tourism industry generated more than $6.1 billion in direct traveler expenditures (up from $5.7 billion in 2007), making it Oklahoma's third largest industry. In addition, annual tax revenues generated by travelers in the state contribute more than $953 million to federal, state, and local economies. Each year, more than 12 million people visit state parks. Oklahoma's tourism industry employs almost 76,000 citizens.

Instream flow uses are considered generally nonconsumptive in nature and may conflict with consumptive water needs (e.g., public water supply, irrigation, etc.). The state's current appropriation system does not contemplate the issuance of water rights for instream/environmental flows, nor does it specifically consider ecological and/or recreational needs when determining water available for appropriation. Many western states, where water is typically scarce and conflicts are more acute, have developed instream flow protection measures in an attempt to resolve disputes between consumptive and nonconsumptive users. Conflicts will escalate in Oklahoma as demands for finite water resources continue to increase. OCWP technical analyses discovered that due to forecasted increases in demands on surface water the magnitude and probability of gaps (shortages) will increase in many basins across the state, greatly increasing the likelihood of periods of low to zero flow. As in many other western states that have grappled with instream flow protection, there remains no clear consensus in Oklahoma on the most appropriate way to balance consumptive and nonconsumptive needs for water. For this reason, stakeholder input and guidance from the recommended Regional Planning Groups could prove invaluable in striking an appropriate balance in each region's unique water needs.

As part of this OCWP update process, an Instream Flow Workgroup was commissioned to conduct an independent technical, legal, and policy analysis of potential instream flow implementation in Oklahoma. A summary of the Workgroup's recommendations are as follows:

1. Address the legal and policy questions.
2. Study other mechanisms for protecting instream flows.
3. Develop a draft methodology for instream flow studies in Oklahoma.
4. Conduct a study on the economic impacts of instream flows in Oklahoma.
5. Perform an instream flow pilot study in a scenic river.
6. Preserve the Instream Flow Workgroup.

(The full report of the OCWP Instream Flow Workgroup is available on the OWRB's website or by contacting the OWRB.)

Implementation Plan

Concurrent Activities/Timelines	
Policy Research & Advisory Group Direction	Technical/Economic Research, Methodology Development & Pilot/Stream Studies
February 2012-July 2015	February 2012-April 2015
Total New Funding Requirement	
$1,500,000 (Total)	~$350,000 (Annual/4 years)

State/Tribal Water Consultation & Resolution

To address uncertainties relating to the water rights claims by the Tribal Nations of Oklahoma and to effectively apply the prior appropriation doctrine in the fair apportionment of state waters, the Oklahoma Governor and State Legislature should establish a formal consultation process as outlined in the OCWP Report on Tribal Issues and Concerns.

Building Cooperation to Avoid Future Conflict and Remove Uncertainties to Water Use

There has been long-standing uncertainty regarding Tribal claims to the waters within Oklahoma that are managed and protected by Oklahoma's environmental agencies. Recommendations from OCWP participants and OWRB staff seek to remove this cloud of uncertainty through establishment of a formal consultation process to amicably resolve this issue and avoid potential costly, protracted litigation. Resolution of Indian water rights claims will assist in the proper implementation of Oklahoma's appropriation doctrine and long-term water planning efforts.

The following recommendations from the OCWP Report on Tribal Issues and Concerns are the result of extensive discussions between Dr. Lindsay Robertson, University of Oklahoma Professor of Law, and representatives of several of Oklahoma's Tribal Nations. This effort was commissioned by the OWRB to identify the state's pertinent water-related tribal issues and offer appropriate recommendations concerning water rights claims and mutual water interests:

1. That the state determine who within state government has the authority to approve a process for negotiation of water rights issues with Tribes, who within state government has the authority to conduct such negotiations, and what the approval process is once negotiations are complete.
2. That the state assemble a team fully authorized to meet with Tribal representatives to devise a process for the discussion and resolution of Tribal water rights claims.
3. That upon the determination of process, the state appoint a fully authorized negotiating team to begin discussions with Tribal representatives.
4. That upon the conclusion of negotiations (either individual, group, or otherwise, as determined by the process planners), the results be submitted for such state approval as is required by law.
5. That the state consider the implementation of regular consultation protocols.

(The full Report on Tribal Issues and Concerns is available on the OWRB's website or by contacting the OWRB.)

Implementation Plan

Title 74 Oklahoma Statute, Section 1221 currently authorizes the Governor or named designee to negotiate and enter into cooperative agreements with Federally recognized Tribal Governments. Additionally, the statute gives the Legislature approval authority over such agreements. Therefore, it is appropriate for these entities to determine the most appropriate way to implement this recommendation.

Water Conservation, Efficiency, Recycling & Reuse

To address water shortages forecasted in the *2012 Update of the Oklahoma Comprehensive Water Plan*, as well as avoid the costly development of new supplies and infrastructure, the OWRB and other relevant agencies should collaborate with various representatives of the state's water use sectors—with particular emphasis on crop irrigation, municipal/industrial, and thermoelectric power—to incentivize voluntary initiatives that would collectively achieve an aggressive goal of maintaining statewide water use at current levels through 2060. In its associated evaluation of appropriate programs and policies, the state should identify the optimum financial incentives, as well as recognize the potential for lost water provider revenues resulting from improved conservation. In particular, the following should be considered:

- Implementation of incentives (tax credits, zero-interest loans, cost-sharing initiatives, increasing block rate/ tiered water pricing mechanisms, etc.) to encourage improved irrigation and farming techniques, efficient (green) infrastructure, retrofitting of water-efficient infrastructure, use of water recycling/reuse systems in new buildings, promotion of "smart" irrigation techniques, control of invasive species, artificial recharge of aquifers, and use of marginal quality waters (including treated gray and wastewater).
- Expanded support for education programs that modify and improve consumer water use habits.
- The applicability of existing or new financial assistance programs that encourage Oklahoma water systems to implement leak detection and repair programs that result in reduced loss and waste of water.

Innovative Solutions to Forecasted Water Shortages

Water conservation is being recognized as an increasingly important tool in managing water resources. Benefits associated with the efficient use of water include increasing water availability for both consumptive and nonconsumptive needs (such as recreation and fishing), reduced energy and infrastructure operation costs, proactive drought mitigation, expansion of water-efficient technology, and reduced need for inter-basin transfers of water. From a larger water management perspective, conservation can be implemented on both the demand and supply/distribution side.

Specific to the *2012 OCWP Update*, increasing water efficiencies to help meet future demands was widely supported throughout the public input process. Furthermore, OCWP technical analyses specifically evaluated conservation potential in the state's two largest demand sectors (municipal/industrial and crop irrigation) to quantify water demand reductions. The OCWP analyzed a suite of conservation activities, including a cost-benefit analysis to characterize associated energy and cost savings. For each water use sector, two scenarios were analyzed, one considering moderate levels of conservation (Scenario I), the other more substantial levels of conservation (Scenario II), both of which demonstrated the feasibility of achieving significant reductions in future demands for water. Various practices and recent trends in conservation were considered for the two sectors, including wider implementation of plumbing codes or more aggressive building code requirements, water use metering, tiered water rate structures, regional irrigation practices, improvements in water conveyance systems, acreages and types of irrigated crops, types of irrigation systems, seasonal rainfall variations, water availability, fuel and commodity prices, trends in irrigation efficiency, improvements in field application efficiency, increased use of micro irrigation technology, and shifting to less water demanding crops. Water conservation, efficiency, recycling, and reuse activities are eligible for funding under the Clean Water and Drinking Water State Revolving Fund Loan Programs.

The OCWP analysis indicates that full implementation of Scenario I would reduce 2060 water demands to levels approaching those forecasted for 2020. Additionally, full implementation of Scenario II, or at least some of its components, would result in facilitation of the ambitious goal set forth in the recommendation. In most basins, managing water demand through conservation activities was shown to be equally effective in reducing or eliminating gaps or storage depletions, particularly in alluvial aquifers. More specifically, a moderate level of conservation (Scenario I) could reduce surface water gaps statewide by 25% and reduce the number of basins with projected surface water gaps from 55 to 42; reduce alluvial groundwater depletions by 32% (from 63 basins to 51); and reduce bedrock groundwater depletions by 15% (from 34 basins to 26).

The OCWP Marginal Quality Water Workgroup studied the potential utilization of several categories of water sources—such as brackish groundwater, treated wastewater effluent, production water from oil and gas operations, and stormwater runoff—demonstrating marginal quality. It was concluded that certain sources could augment supply in some areas of Oklahoma. In particular, treated effluent showed promise in helping to meet future demand, especially for municipal/ industrial non-potable, crop irrigation, thermoelectric power, and self-supplied industrial uses. However, local applicability and regulatory requirements must be considered.

A second OCWP workgroup, the Artificial Aquifer Recharge Workgroup, determined that artificial recharge of groundwater is also a viable option in augmenting supplies to meet future demands in several areas of the state. Five sites were identified across the state where recharge demonstration projects could be most feasible.

(The full reports of the Marginal Quality Water and Artificial Aquifer Recharge Workgroups are available on the OWRB's website or by contacting the OWRB.)

Water Supply Reliability

To address projected increases in water demands and related decreases in availability, as well as to ensure the fair, reliable, and sustainable allocation of Oklahoma's water supplies, the State Legislature should provide stable funding to the OWRB to implement the following recommendations:

- Address by 2022 the growing backlog of statutorily-required maximum annual yield studies and overdue 20-year updates on groundwater basins within the state, including validation of any interactions between surface and groundwater sources, to accurately determine water available for use.
- Develop stream water allocation models on all stream systems within the state to assess water availability at specific locations, manage junior/senior surface water rights under various drought scenarios, anticipate potential interference between users, and evaluate impacts of potential water transfers.
- Utilize water use stakeholders (including input from the recommended Regional Planning Groups), researchers, and other professionals to develop recommendations, where appropriate, regarding:
  a. consideration of a seasonal (rather than annual) stream water allocation program to address seasonal surface water shortages and water rights interference;
  b. consideration of a conjunctive management water allocation system to address the potential decline in surface water flows and reservoir yields resulting from forecasts of increased groundwater use in areas where these sources are hydrologically connected;
  c. conditioning junior water use permit holders to discontinue their diversion of water during predetermined periods of shortage (i.e., "trigger" points) to enhance the availability of dependable yields in appropriate reservoirs and minimize interference between riparian users and users of reservoir storage; and
  d. consideration of a more conservation-oriented approach in the calculation of groundwater basin yields and allocation of groundwater use permits, including the consideration of more sustainable use and development of groundwater supplies, allocation banking coupled with an accurate method of accounting, irrigation practice improvements, and adoption of new irrigation technology.

Ensuring Water Availability for Future Growth

The OCWP anticipates that statewide consumptive water demand will increase by 34% over the next 50 years, not accounting for implementation of water efficiency measures, yet forecasts vary regionally from 20% to 58%. Particularly in populated areas, growth will put an even greater stress on available water supplies. Factors associated with increased demand vary as well. Regardless, it is incumbent upon the OWRB, as the state's water management agency, to ensure reliability for all state water users. OCWP technical analyses concluded that forecasted demands will increase the magnitude and probability of monthly surface water gaps and groundwater storage depletions in the majority of basins, particularly during the summer months. For surface water it was found that in many of those basins water storage collected during periods of high flow could greatly reduce or even eliminate shortages.

Based upon recommendations from the public and OWRB staff, several aspects of the state's current approach to water management require the evaluation of new or enhanced management schemes—including the possible implementation of new policy and clarifications to existing statutes and rules—that promote conservation to maximize existing water rights and create assurance that water resources will be available when and where required. Because future water management programs and decisions should consider regional variability, recommended Regional Planning Groups could lend important guidance to these efforts. Reviewing the approaches and experiences of neighboring states, such as Kansas, could prove valuable as well.

Additional concerns have been raised about protecting the yield of reservoirs, particularly by some appropriation right holders that authorize use of water from storage reservoirs constructed by federal agencies. During low flow or drought conditions, there is no good mechanism currently in place to notify junior upstream appropriators if interference is occurring or to enforce curtailment of ongoing diversions, thus reducing the dependability of many reservoirs in delivering water supply to users. Reservoirs are critical to water supply reliability in Oklahoma. Currently, 82 percent of public water supply systems obtain their water from reservoir storage.

Implementation Plan

Hydrologic Studies (Phase I)

Unstudied and Overdue Groundwater Basin Updates Estimated Annual Cost	Stream Water Hydrologic Studies Estimated Annual Cost	Timeline
$1,045,000	$73,125	2012-2022

Hydrologic Studies (Phase II)

20-Year Groundwater Basin Updates Estimated Annual Cost	Stream Water Hydrologic Studies Estimated Annual Cost	Timeline
$342,134	$18,750	2023-2060

Total New Annual Funding Requirement

$1,118,125 (Phase I)	$360,884 (Phase II)

Water Quality & Quantity Monitoring

The State Legislature should provide a dedicated source of funding to enable the State of Oklahoma to accurately assess the quality and quantity of its water resources, thereby ensuring improved water quality protection, accurate appropriation and allocation, and long-term collection of data to make informed water management decisions. Such funding should be directed toward development and maintenance of a permanent statewide water quality and quantity monitoring program(s), specifically allowing for the following:

- Integration of all state surface and groundwater quality monitoring programs into one holistic, coordinated effort.
- Stable and dedicated appropriations for critical statewide monitoring programs, such as Oklahoma's Cooperative Stream Gaging Program, Beneficial Use Monitoring Program, and Nonpoint Source Monitoring Program, as well as other agency efforts to monitor point source, agriculture, mining, and oil and gas impacts.
- Creation of an ambient groundwater quality monitoring program.
- Full implementation of a statewide program for the collection of biological data to provide a better indication of long-term water quality trends in Oklahoma.

Better Data for Improved Decision-Making

Most contributors to the *2012 OCWP Update*, including an overwhelming number of public participants, recognize the urgent need for more robust data gathering programs to enable informed decision-making. Several state and federal agencies—including the U.S. Geological Survey, Army Corps of Engineers, Oklahoma Water Resources Board, Conservation Commission, and Department of Environmental Quality—administer programs in Oklahoma that provide invaluable data regarding the state's water quality and quantity. However, funding for these programs has continued to dwindle. The most acute funding need is establishment of a holistic statewide surface water and groundwater monitoring program to accurately assess the quality and quantity of those resources.

Recognizing its significance to ensuring a reliable supply, OCWP technical analyses explicitly considered water quality among those critical factors limiting future use of surface water supplies. Unfortunately, such a comprehensive evaluation could not be performed for groundwater given the lack of statewide ambient groundwater quality data.

Implementation Plan

Surface Water Quality Monitoring

Current Annual Funding	Additional Estimated Annual Cost	Timeline
$800,000	$975,000	2012

Surface Water Quantity Monitoring

Current Annual Funding	Additional Estimated Annual Cost	Timeline
$120,000	$445,000	2012

Groundwater Quality/Quantity Monitoring

Current Annual Funding	Additional Annual Cost	Timeline
$0	$815,000	2012

Total New Annual Funding Requirement

$2,235,000

Supporting Recommendations & Initiatives

Nonpoint Source Pollution

Voluntary best management practices should be encouraged to curtail runoff from agricultural lands, urban storm water, and suburban developments. These voluntary management practices should include cost sharing or incentives funded through the appropriate state agency(s). Specifically, the Oklahoma Conservation Commission (OCC) and other appropriate agencies should create or enhance programs that promote water quality improvements through land use management and the protection of wetlands and riparian zones. Additionally, the OCC should emphasize roadside erosion and resulting sediment as a major contributor to water quality degradation. The OCC or other appropriate agencies should work with county commissioners to improve or fund proper construction and maintenance of roads to reduce sediment contribution. Finally, the OCC should continue to support nonpoint source water quality monitoring programs that can evaluate the effectiveness of these conservation practices and ensure maximum efficiency of available funding.

While much progress has been made, nonpoint source pollution continues to be a significant contributor to water quality impairment in Oklahoma. Efforts to mitigate these impairments should be implemented within the watershed and receiving waters targeting the restoration of impaired beneficial uses. There are many excellent programs that exist currently that, with additional funding, could be even more effective in reducing pollution from nonpoint sources.

The OCC, working with the USDA, EPA, and other state, federal, and local partners, implements Farm Bill conservation programs, the CWA Section 319 program, a State-funded, locally-led cost share program, and a roadside erosion program to promote and demonstrate voluntary best management practices to improve water quality, reduce soil erosion, minimize pollution, and protect surface and groundwater resources. Publicly or privately owned projects that implement nonpoint source management programs established under section 319 may also be eligible for funding under the CWSRF Loan Program. Categories of eligibility may include stormwater projects, water conservation and reuse, source water protection, contaminated sites, animal feeding operations, failing decentralized wastewater systems, landfills, trading, land, atmospheric deposition and water quality monitoring.

With all of these programs and promotion of best management practices in both rural and urban environments, Oklahoma is working to maintain and protect water quality. These highly successful programs have documented success; however, funding limits widespread implementation. To adequately supplement USDA Farm Bill conservation programs and the CWA Section 319 program, the state should fund the Oklahoma Conservation Commission water quality cost share programs at a minimum level of $15 million annually.

Maximizing & Developing Reservoir Storage

The Oklahoma Water Resources Board, Oklahoma Conservation Commission, Natural Resources Conservation Service, and other appropriate agencies should work collaboratively to develop a cooperative process to maximize the flood control, water supply, recreation, ecological integrity, and related benefits of existing reservoir projects as well as identify the potential viability of those designated for construction in the state. Both state and federal funds should be used to improve existing lakes or build future projects.

Over the last 60 years the USDA in partnership with local project sponsors and the OCC have constructed over 2,100 flood control structures (dams) within Oklahoma. Several of these structures are multipurpose in nature providing for water supply and recreation in addition to flood control. There are many excellent proposed sites and existing dams in need of rehabilitation that could provide additional multi-purpose benefits. For example, as a part of rehabilitation, existing structures could be converted to provide additional or new water supply yield. Adequate funding, essential to maintaining the important functions these dams have provided for the last 60 years, has been declining.

Projects that address source water protection may be eligible for funding under the CWSRF Loan Program. Eligible activities include tree plantings and other protection activities that take place in wellhead protection or surface water drainage areas. Procurement of land for smaller reservoirs (including the impoundment or dam) may be eligible for funding under the CWSRF Loan Program if implementation or rehabilitation of the project would provide a direct, measurable water quality benefit.

Water Management & Administration

1. To ensure the efficient use and conservation of state water resources, the Oklahoma Water Resources Board should take the following action:
   a. Provide for a suspension period from water rights cancellations due to non-use if the nonuse is a result of the water rights holder actions to employ prescribed conservation measures, such as irrigating crops that are more water-efficient or implementing water system leak detection or rationing programs.
   b. Work with the State Legislature to establish stable funding necessary for the agency to increase field verifications that ensure compliance with surface and groundwater use permit requirements and investigate specific cases of water interference.
   c. Institute an administrative fining system for unlawful or unpermitted use of water, willful failure to report water use, or falsification of water use report forms.

2. To prevent contamination of fresh groundwater sources, the OWRB should take the following action:
   a. Investigate potential methods to equitably regulate the use of moderately brackish groundwater sources in a manner that protects fresh water aquifer zones.
   b. Work with the Oklahoma Groundwater Association and licensed well drillers to identify required funding levels and an appropriate funding mechanism to remediate tens of thousands of existing unplugged or improperly plugged abandoned water wells statewide.
   c. Establish a workgroup to investigate the feasibility of establishing an intent-to-drill system in Oklahoma that would provide appropriate oversight of new water wells, including a mechanism for pre-drilling review and inspection.

Among its core water management responsibilities, the OWRB is charged with many water management and administration duties that protect the interests of water right holders, mitigate hazards, and protect water sources, life, and property. These include managing water rights in times of drought, ensuring water use permit compliance, inspecting water works and dams, responding to complaints of waste of water or interference between water users, and licensing and regulation of well drillers to prevent contamination of groundwaters. Although never fully funded, these activities are fundamental to the state's water management and additional resources are required to accomplish these vitally important activities.

Dam Safety & Floodplain Management

To mitigate catastrophic flooding hazards and protect lives, property, and water supplies, the state should take the following action:

- Continue to support local floodplain management efforts through developing cooperative partnerships with local communities and federal agencies to fund technical studies and floodplain mapping, develop floodplain ordinances, and promote education activities, including the certification of floodplain administrators.
- Investigate the potential for establishing a financial assistance program for the state Dam Safety Program to make low-interest loans to dam owners to meet mandated changes to dams required through reclassification of the dam to a higher hazard-potential due to downstream development.
- Provide $250,000 per year for ten years to the OWRB to perform dam breach inundation mapping and emergency action planning, and education and outreach efforts that support the state Dam Safety Program for non-NRCS flood control dams, with a priority on high hazard-potential dams.
- Provide $12 million in funding and support to the OCC to perform dam breach inundation mapping, emergency action planning, and education and outreach efforts that supports dam safety for NRCS flood control dams.
- Expand floodplain management authorities and floodplain ordinances to include dam breach inundation areas and investigate establishment of potential disincentives or fee requirements for downstream development in the dam breach inundation area adequate to fund the cost of upgrading NRCS flood control dams to meet State dam safety criteria.
- Identify a mechanism to remove liability of dam owners for downstream development occurring after an NRCS flood control dam was constructed.

There are 4,446 dams under the Oklahoma Dam Safety Program, regulated by the OWRB, which also coordinates state hazard-prevention programs through the National Flood Insurance Program in cooperation with the Oklahoma Floodplain Managers Association. (Currently, 384 Oklahoma communities participate in the NFIP.) An estimated 360 dams classified as significant- and high-hazard potential have structural deficiencies requiring rehabilitation. In addition, an estimated 800 of the state's dams currently classified as low hazard-potential should be reclassified due to significant downstream development, requiring costly upgrades, breach inundation mapping, and emergency action planning. An estimated $22 million is required to bring state flood control dams into compliance with legally binding federal operation and maintenance requirements. State-mandated requirements demand approximately $457 million to upgrade flood control dams to meet high-hazard criteria due to unregulated downstream development.

Water Quality Management

Local, state, and federal agencies and tribal governments should continue to work collaboratively towards continued protection and improvement of Oklahoma's surface and groundwater quality. Programs, both regulatory and non-regulatory, that contribute to improvements and maintenance through point source and nonpoint source pollution control, monitoring and assessment, and impairment reduction should be adequately funded at both the state and federal level. In particular, Oklahoma must have a robust statewide surface water and groundwater quality monitoring network to ensure programs and policies are working effectively and funds are being used to the greatest benefit possible.

As it relates to a reliable water supply, the quality of the state's waters is critically important. Quality is a significant factor in water's ability to provide invaluable environmental, recreational, and aesthetic benefits to Oklahoma. It directly impacts infrastructure and associated costs required to treat water for various uses. Primary elements of water quality protection and continued improvement include point and nonpoint source pollution control, monitoring and assessment, and programs and activities focused on impairment reduction. Over the last several decades, incredible strides have been made by various local, state and federal agencies and tribal governments to improve and maintain Oklahoma's water quality; however much work remains. In Oklahoma, a myriad of state and federal agencies and tribal governments have a role in the management of the quality of the state's water. Recognizing the critical nature of water quality and the number of entities involved in its management and protection, a working group was commissioned for the OCWP to provide program information related to these organizations and agencies and to make collective recommendations to address Oklahoma's most pressing water quality issues, including program requirements. *(The full report, OCWP Water Quality Issues and Recommendations, is available on the OWRB's website or by contacting the OWRB.)*

Navigation

The OWRB should continue its active participation with the Oklahoma Department of Transportation's Waterways Advisory Board and through that group proactively address issues of mutual interest concerning water management and availability. The OWRB and Advisory Board should work toward cooperative solutions that ensure the continued successful operation and growth of navigation in Oklahoma.

The McClellan-Kerr Arkansas River Navigation System is a major economic engine for the state. The Oklahoma portion alone includes an estimated 100 industries, 4,000 employees, and an annual payroll approaching $100 million. According to studies conducted by public and private stakeholders within the last two years, capital investment was reported at $3.9 billion, employment income of $142 billion, and operating expenditures of $1.4 billion from the capital investments that contribute to the creation of many secondary and tertiary jobs and industries.

Interstate Water Issues

The state should explore the creation of standing planning committees through existing interstate stream water compacts or other federal/state forums to work proactively with neighboring states on shared water resource management issues and thus limit potential interstate conflicts and litigation.

Recognizing that all streams in Oklahoma flow from other states and into others, it is important to collaborate on water management issues of mutual interest. Several existing forums or mechanisms—including four interstate stream compacts and state and federal participation in annual meetings of the Arkansas-White-Red Basin Inter-agency Committee—could be utilized to further address interstate conflicts over shared waters. Formalizing discussion of water planning issues and projects, both state and federal, could be beneficial to proactively avoid potential conflicts and litigation and to facilitate collaboration on mutually beneficial initiatives.

Source Water Protection

The State—through the DEQ, OWRB and/or OCC—should provide technical assistance to public water systems for the development of source water and wellhead protection plans that reduce the threat of pollution to public water supplies.

Avoiding pollution to sources of water is much more cost-effective than mitigating resulting impacts. The OCC develops watershed protection and restoration plans to identify potential pollution sources in the watershed of water supply reservoirs and works with local landowners to minimize associated impacts. The DEQ currently works with water providers to assure upstream water quality protection, and it implements a wellhead protection program to protect groundwater. The OWRB applies lake management tools to public water supplies in order to minimize treatment/infrastructure costs and health risks associated with organic enrichment. The OWRB also protects water supplies through Oklahoma's Water Quality Standards (OWQS) by limiting new pollution sources or increased loads from existing sources upstream of Sensitive Water Supplies. The OWQS further identify aquifers with a high potential for contamination from surface sources to promote the proper site selection and management of potential surface contaminants. While these programs have been successful, they are currently unable to adequately address the issue statewide. A coordinated and well-funded effort is required.

Water Emergency/Drought Planning

The Oklahoma Drought Management Plan should be updated and expanded to specifically address water emergencies—including an assessment of causes, impacts and capabilities—as well as improved state, federal and local response to flooding, terrorism and water contamination. Additionally, the DEQ should include a water and wastewater emergency planning component in its municipal water system operator training program. The state should also evaluate risks associated with various types of water emergencies and encourage local entities to incorporate similar measures through incentives and technical assistance.

As a part of the OCWP process, the public voiced a very strong desire to enhance water providers' ability to plan for and respond swiftly and appropriately to water related emergencies. Such emergencies include drought, flooding, water supply contamination and terrorism. Several programs exist to address such issues; however, enhancements are needed. Specifically, the Oklahoma Drought Management Plan, originally written in 1997, requires an update to reflect current lines of authority and responsibility that impact how water systems, cities, counties, and state and federal agencies respond to drought, including the latest procedures addressing state or federal assistance. The plan does not specifically address the causes, impacts, and response to general water emergencies.

Additionally, the DEQ oversees an Operator Certification program that trains and licenses drinking water and wastewater facility workers to ensure they are trained to sufficiently treat and monitor by-products of the facilities. With adequate funding, such a program would provide an excellent training forum on water-related emergencies.

Water Supply Augmentation

A statewide process should be developed and implemented to evaluate the augmentation of water supplies through programs to manage invasive plant species, increase water filtration and reduce runoff.

Current programs to eliminate eastern red cedar, salt cedar and other invasive species may positively impact the water balance. Similar benefits could also be realized by increasing water filtration rates and reducing runoff through the addition of soil organic matter and land contouring. There is a need to further investigate these efforts and their potential to augment water supplies. Eventual widespread programs will require a coordinated approach involving private property owners, local communities, and county, state and federal partners. Tax incentives, cost-share programs and technical assistance will be vital to eventual success.

Water-Related Research

- **The state should encourage the establishment of collaborative forums consisting of state, federal, local and tribal representatives to coordinate and prioritize ongoing water research activities at the state's many universities. When appropriate, cross-institutional teams should be formed to compete for grant opportunities.**

- **The state should establish regular appropriations to fund Oklahoma's critically important university water research units, including the Corix Water Institute; Oklahoma Water Survey and Oklahoma Climatological Survey at the University of Oklahoma; and the Oklahoma Water Resources Research Institute and Water Research and Extension Center within the Division of Agricultural Sciences and Natural Resources at Oklahoma State University.**

- **The state should focus resources on the pursuit of the following priority water-related research needs, consistent with citizen and workgroup input provided throughout development of the** *2012 OCWP Update:*
  - **Maximize the use and efficiency of water used to support Oklahoma's vital agriculture industry.**
  - **Better understand and quantify the role played by water in support of the environment and related ecological and recreational benefits.**
  - **Develop practical, state-of-the-art predictive tools for use by water managers and users that are imperative to decision-making and in mitigating the impacts of drought episodes, floods, and the state's dynamic climate.**
  - **Increase knowledge related to the interaction between waters in the state's alluvial aquifer and stream systems.**
  - **Enhance the general knowledge base of Oklahoma's climate and explore measures to collaboratively apply that knowledge to a multitude of sectors.**
  - **Supplement knowledge of Oklahoma's groundwater resources. Establishment of a statewide groundwater quality and quantity program is imperative to this effort.**

A significant understanding of Oklahoma's water issues can be accomplished through frontiers of research and the practical application of that research for the benefit of the state's citizens. Oklahoma's universities have developed strong programs in a number of specific water related fields, and such expertise has proven critically important to such matters as water quality protection and improvement, water use, conservation and efficiency, land use practices and informing policy decisions. It is imperative that the state support the continued development and advancement of research programs to assist water users and managers in answering some of Oklahoma's most pressing water issues. Many of these issues have been highly informed as a result of the *2012 OCWP Update*.

Agricultural Water Research

Recognizing Oklahoma's successful and vital agriculture industry, the State and other local, federal and tribal agencies, should continue to work collaboratively with representatives of the agriculture industry. More specifically, the State should support research, education and extension activities to address the issues identified in the OCWP *Agricultural Water Issues and Recommendations* **report.**

Recognizing that agriculture is Oklahoma's largest industry and that water is vital to its continued success, the OCWP commissioned Oklahoma State University's Division of Agricultural Sciences and Natural Resources to develop a report on agricultural water issues and make appropriate recommendations regarding research, education and extension opportunities.

As of 2008, the direct impact of the Oklahoma agriculture sector, including production and processing, was estimated to be approximately $20.1 billion; the total impact of the agriculture sector on the state's overall economy was estimated at $28 billion. Water plays a pivotal role in the irrigation of cropland, in the watering of livestock and in the production of turfgrass. For example, irrigated cropland is about 27% more valuable than non-irrigated cropland, primarily because of increased productivity and reduced risk compared to rain-dependent agriculture. Livestock production, particularly beef cattle, and aquaculture account for about 12% of statewide water use; Oklahoma ranks third, behind only Texas and California, in freshwater withdrawals for cattle production. Turfgrass production, also heavily dependent upon water, is another major agriculture industry in Oklahoma with sales in excess of $40 million as of 2007. *(The full report, OCWP Agricultural Water Issues and Recommendations, is available on the OWRB's website or by contacting the OWRB.)*

Climate & Weather Impacts on Water Management

The Oklahoma Water Resources Board and other appropriate local, state and federal agencies and tribal governments should continue to collaborate with and support the Oklahoma Climatological Survey to continue the advancement of a thorough understanding of Oklahoma's climate and weather, as outlined in their recommendations, and the associated impacts on Oklahoma's water users and citizens. Furthermore, the State Legislature should support the activities of the OCS to ensure that the agency can adequately address Oklahoma's needs related to these matters into the 21st century.

For water users, managers and policy makers across the state, an understanding of Oklahoma's climate and weather is critically important. The timing, frequency and magnitude of precipitation and variability in temperature directly affect water availability, drought, flooding and other weather phenomena. For over 30 years the Oklahoma Climatological Survey has been the lead agency for informing stakeholders about Oklahoma's climate and weather and for providing data and tools to make this information understandable and usable for the benefits of the state's citizens and water users. The OCS was established by the State Legislature in 1980 and maintains an extensive array of climatological information, operates the Oklahoma Mesonet, and hosts a wide variety of educational outreach and scientific research projects.

The Oklahoma Mesonet is a world-class network of environmental monitoring stations and was designed and implemented by scientists at the University of Oklahoma and Oklahoma State University. The Mesonet consists of 120 automated stations covering Oklahoma. Mesonet stations report real-time weather and climate information every five minutes from every county in Oklahoma.

Understanding the important role climate and weather have in Oklahoma's water future, and recognizing the legislative mandate and expertise of the Oklahoma Climatological Survey, the OCWP commissioned a report from the OCS to identify research and outreach needs critical for Oklahoma's water future. *(The full report, OCWP Climate Issues and Recommendations report, is available on the OWRB's website or by contacting the OWRB.)*

Water Resources Planning in Oklahoma

Long-range planning to protect and maximize the benefits of the state's surface and groundwater resources has been a continuing mission of the state since the 1950s, as demonstrated through such planning milestones as the creation of the *1980 Oklahoma Comprehensive Water Plan* (OCWP). Recognizing that water planning is a discipline that must provide for continuous change and periodic revision if it is to reflect dynamic social, political, economic, and environmental issues, the Oklahoma Legislature passed House Bill 2036 in 1992. The legislation directed the Oklahoma Water Resources Board (OWRB) to prepare an update of the *1980 OCWP*, resulting in the *1995 Update of the Oklahoma Comprehensive Water Plan*. HB 2036 also directed the OWRB to prepare decennial updates thereafter, thus mandating for the first time regular submittals of updated water plans in addition to implementing a continual planning process. The *2012 Update of the Oklahoma Comprehensive Water Plan* responds to this mandate.

Plan Organization

With the primary objective of establishing a reliable supply of water for state users through the next 50 years and beyond, the *2012 OCWP Update* represents the most ambitious and intensive water planning effort ever undertaken by the state. The *2012 OCWP Update* is guided by two ultimate goals:

1. Provide safe and dependable water supply for all Oklahomans while improving the economy and protecting the environment.
2. Provide information so that water providers, policy makers, and water users can make informed decisions concerning the wise use and management of Oklahoma's water resources.

In accordance with these goals, the *2012 OCWP Update* has been developed under an innovative parallel-path approach: inclusive and dynamic public participation to build sound water policy complemented by detailed technical evaluations.

Also unique to this update are studies conducted according to geographic (watersheds) rather than political boundaries (counties). This new strategy involved subdividing the state into 82 planning basins for water supply availability analysis. Where practical, existing watershed boundaries were revised to include a U.S. Geological Survey (USGS) stream gage at or near the basin outlet. To facilitate consideration of regional supply challenges and potential solutions, basins were aggregated into 13 distinct Watershed Planning Regions. In many cases, aquifer boundaries extend across multiple planning basins and regions.

Based upon the results of technical studies, thirteen Watershed Planning Region Reports were prepared for the *2012 OCWP Update*. Each regional report presents information from both a regional and multiple basin perspective, including water supply/demand analysis results, forecasted water supply shortages, potential supply solutions and alternatives, and supporting technical information. They have been designed as "living" documents that can be readily updated to reflect constantly changing water resource data and key demographic and economic information.

Integral to data analysis and development of these reports was the Oklahoma H2O model, a sophisticated database and geographic information system (GIS) based analysis tool created to compare projected water demands to physical supplies in each OCWP planning basin. Recognizing that water planning is not a static process but rather a dynamic one, this versatile tool can be updated as new supply and demand data become available, and can be used to evaluate a variety of "what if" scenarios at the basin level, such as a change in supply sources, demands, new reservoirs, and various other policy choices.

Primary inputs to the model include demand projections for each decade through 2060, founded on widely-accepted methods and peer review of inputs and results by state and federal agency staff, industry representatives, and stakeholder groups for each demand sector. Surface water supply data for each of the 82 basins used 58 years of publicly-available daily streamflow gage data collected by the USGS. Groundwater resources were characterized using previously developed assessments of groundwater aquifer storage and recharge rates.

Additional information gained during the development of the *2012 OCWP Update* is provided in various supplemental reports. Assessments of statewide physical water availability and potential shortages are documented in the OCWP *Physical Water Supply Availability Report*. Statewide water demand projection methods and results are presented in the *Water Demand Forecast Report*. Water available for permitting is documented in the *Water Supply Permit Availability Report*. All supporting documentation is available on the OWRB's website or by request.

Water Management in Oklahoma

Overview of Water Use and Rights Administration

Sources of Water Law

The right to use water, the right to regulate use of water, the prevention of water pollution, and water quality, are all legal matters that, to some degree or another, may be addressed by constitutional law, court-made (common) law, statutes enacted by the U.S. Congress, statutes enacted by the Oklahoma Legislature, Indian tribal codes, federal and state agency rules, and private rights created by deeds, easements, and contracts. The administration of water use and rights in Oklahoma involves consideration of these and other sources of voluminous and complex law.

Quantity Distinguished from Quality

Oklahoma statutes provide that the Oklahoma Water Resources Board (OWRB), through the agency's nine-member decision-making body appointed by the Governor, is responsible for the appropriation, allocation, distribution and management of water quantity in the state. The OWRB shares responsibility with six other state environmental agencies relative to water quality.

Grand River Exception

An exception to the OWRB's authority to manage water quantity involves the Grand River in northeast Oklahoma. In 1935, state law created the Grand River Dam Authority (GRDA) and provided it authority to control, store, and preserve the waters of the Grand River and its tributaries.

Physical Classifications of Water

Most of Oklahoma's statutes on water rights and use administration are keyed to one of four physical classifications of water: (1) stream water, (2) percolating groundwater, (3) diffused surface water, or (4) atmospheric water, such as rain or hail.

Ownership of Water

As long ago as 1890, Oklahoma Territorial statutes on property ownership, rights and obligations stated that "The owner of the land owns water standing thereon, or flowing under or over its surface, but not forming a definite stream. Water running in a definite stream, formed by nature over or under the surface, may be used by him as long as it remains there; but he may not prevent the natural flow of the stream, or of the natural spring from which it commences its definite course, nor pursue or pollute the same."

This law was carried over verbatim into State of Oklahoma statutes where it remains on the books today in Title 60, Section 60 of the Oklahoma Statutes. In 1963, language was added to clarify that water running in a definite stream is "public water subject to appropriation for the benefit and welfare of the people of this state."

To summarize, the state's property and water laws dictate the following about ownership of water:

- Diffused water (i.e., water flowing over the surface of the earth and not forming a definite stream) is owned by the owner of the land.
- Groundwater (i.e., water flowing under the surface but not forming a definite stream) is owned by the owner of the land.
- Stream water (i.e., water flowing in a definite stream) is public water subject to appropriation.
- The state property law is silent about ownership of rain or hail while it is in the atmosphere.

Although the state statute declares that stream water is "public water," there is often a misperception that this statute creates a claim of ownership of stream water in the State of Oklahoma. The U.S. Supreme Court has characterized a state's claim of ownership as a "legal fiction." The Court instead recognizes that as far back as Roman law, water running in a stream was properly described as "res nullius" or "res communes," meaning the property of no one or property of everyone, like air, natural light, or animals in the wild. Therefore, just as management and use of animals in the wild in Oklahoma are subject to regulation and licensing by the Oklahoma Department of Wildlife Conservation, stream water and certain other physical classes of water are subject to management and use regulation by the OWRB.

General Water Law Doctrines and Principles Relating to Use

Controversies involving use of water, distinguished from ownership of water, have arisen for centuries. The most notable legal doctrines that have been developed by courts (common law) and legislatures (statutes) to address such water use controversies include: (1) riparian rights, (2) appropriation, (3) correlative rights, and (4) allocation.

Riparian Rights

Generally, "riparian rights" are said to exist as an integral part of the ownership of land that happens to be geographically adjacent to or adjoining a stream or other body of water, such as a lake or pond. Some may characterize riparian rights as real property. However, a riparian right is more accurately characterized as only a right of use, or a "usufruct" or "usufructory" right. By the early 1800s, English common law recognized the principle that no one could "own" water running in a stream as a property right, but that private citizens could have a right to the use of its flow. English law recognized the concept of the usufruct, or the qualified right to the use of property that is owned by all or no one ("res nullius or "res communes"), so rights to the use of the flow of a stream became known as usufructory rights.

Historically, the riparian doctrine has been administered though the court system with ad hoc decisions made in individual lawsuits between riparian landowners. There is generally no permit system for riparian rights in states that follow the riparian doctrine, no applications to file, and no administrative hearings held. The riparian rights system of water use regulation evolved in the eastern U.S. where rainfall is more plentiful and most land tracts touch or adjoin some creek, stream, or river. As a result, relatively few disputes and controversies occurred over water quantity. With plenty of water and few controversies, there is little need for regulatory oversight within a riparian system.

There are two major legal doctrines or approaches to resolve riparian rights claims to use water that have been adopted by courts over time, and two other aspects or issues involving riparian rights that have some bearing on Oklahoma water law.

Riparian Rights to the Natural Flow (Stream Water)

English courts in the 1800s decided cases between riparian landowners (often conflicts between grist mill operators) by adopting the principle that any change in the natural flow of the stream by a riparian landowner that uses the water causes damages to other owners of other land riparian to the stream. Therefore, use of water that changes the natural flow is not authorized. The practical problem with this principle is that virtually any use of natural flow, even for very limited household use, let alone grist mills or water mills for industrial use, would alter that flow to some degree. Acknowledging the problem with strict compliance, state courts following the "natural flow theory" of the riparian doctrine began to make exceptions to allow limited use by riparian landowners. Today, few states are known to follow a true "natural flow" doctrine of riparian rights.

Riparian Rights to Reasonable Use (Stream Water and Groundwater)

The famous case of Tyler v. Wilkinson between competing mill owners in Rhode Island was decided in 1827 by Justice Story (later appointed to the U.S. Supreme Court). He declared that rights between riparian landowners required a consideration of reasonableness to determine whether a change in natural flow was allowed. He also ruled that all riparian users would have to reduce their use equally in times of shortage.

Unlike an appropriation right, a riparian right (being part of the real property) is not automatically lost if the riparian landowner makes no use of the water or if the riparian landowner begins use for a period, stops use, and begins the same use or changes use in the future. Each riparian landowner has the same right, limited only by its reasonableness.

In a state that follows the reasonable use riparian doctrine, conflicts and controversies regarding water use between riparian landowners are typically resolved in court litigation with the focus on determining reasonableness of types of use, volume, timing, and methods of use. Due to the number of variables in determining whether a use is reasonable, the doctrine of riparian rights cannot provide the certainty and security necessary for substantial development (e.g., public water supply infrastructure, irrigation systems, reservoirs, etc.) of water resources required for economic growth.

In Oklahoma, despite the pre-statehood Legislature's adoption of the natural flow language, the Oklahoma Supreme Court decided several cases before 1963 using a "reasonableness" analysis to resolve disputes between riparian landowners. In 1993, the Oklahoma Supreme Court issued its 5 to 4 opinion in Franco-American Charolaise, Ltd. v. OWRB, wherein the Court declared that Oklahoma follows the "reasonable use" doctrine, as opposed to the natural flow doctrine.

Appurtenancy of Riparian Lands

States that endorse a riparian doctrine for water rights (natural flow or reasonable use) must also decide the geographic extent of the land area that may carry the riparian right. The "source of title" test, used in some riparian doctrine states, holds that the riparian right extends only to the smallest tract held under one title in the chain of title leading to the present owner. Following this test, the size of the riparian tracts typically diminish over the decades as tracts are subdivided (through inheritance or other development) and the new tracts do not touch the stream. This test typically results in less water being claimed by riparian landowners over time.

The contrasting "unity of title" test used in other riparian doctrine states provides that if an owner of a tract of land that is riparian later acquires more land that adjoins the original riparian tract, the owner may claim a riparian right for use of water on both tracts because the adjoining tract becomes "unified" with the riparian tract as a whole. This test may result in more water being claimed in a stream system by riparian landowners over time.

In Oklahoma, judges in two cases ruled that an oil company holding a lease for water use from a riparian landowner could use the water off the riparian lands for oil drilling purposes as long as that use was reasonable. With these cases, it can be argued that Oklahoma went beyond the unity of title test and allowed riparian landowners to market water for use off the riparian premises, regardless of the location of the land where the water was used.

Regulated Riparianism

With increased demand for water in the relatively water-rich eastern U.S. where the riparian rights doctrine prevails, coupled with more variability of natural rainfall (more extreme and longer droughts), some states that follow the riparian doctrine have seen a need to exercise more oversight of water use. These states have enacted laws requiring that riparian landowners obtain permits to use water, a concept that was foreign to the common law of riparian rights where rare disputes were resolved in courts.

Appropriation Doctrine (Stream Water and Groundwater)

To "appropriate" means to take for oneself or take possession of. Literally, it means taking water from a watercourse (flowing stream or lake). The appropriation doctrine for water management and use evolved from local customs and laws in the early and mid-1800s, primarily from Spanish, Mexican, and Mormon operations of diversions and canal systems for irrigation. These local customs and laws were developed in the arid western U.S. during the time of westward expansion by settlers and where land areas tended to be vast but sources of water were scarce. In other words, unlike the wet east where many tracts of land are riparian to a water source, most private tracts of land in the western states were not riparian to a stream, but instead were often located at some distance from a stream, requiring diversions from the water source to the location of use. Furthermore, most lands in the western U.S. at least initially were considered public lands (or in the public domain) owned by the U.S. With little private ownership of most lands, there were few instances of privately-owned riparian land for riparian water rights to exist. In 1849, the California Supreme Court, during the gold rush era, was the first to determine that local customs to resolve mining claims on public lands should be used to resolve disputes over use of water on those lands. With mining claims, the earlier claim would prevail over a later claim to mine the same land, and the failure to start mining activities, or to continue mining activities after starting, would result in a loss of the mine claim and allow others to have a similar opportunity.

Two fundamental and parallel concepts relating to mining claims and water appropriation claims were recognized:

1. "Beneficial use" is required. Filing a piece of paper at the claim office only initiated a mine claim and the claim was lost if mining activities did not commence within a certain period of time, or if the mine was later abandoned. Similarly, a claim to use water from a stream had to be confirmed by actual beneficial use of the water. The requirement for beneficial use is characterized as the "anti-speculation" provision that prohibits the filing of paper rights to prevent others from getting a right that can be detrimental to economic development;
2. "Priority in time gives the better right." Similar to mining claims in California, whoever files a claim to use water from a stream first (senior) and places that water to beneficial use will be able to make persons with later (junior) claims stop diverting during times of shortage.

These two foundational elements of the appropriation doctrine, recognized over 150 years ago, remain in Oklahoma's appropriation doctrine. Congress, recognizing the need for a secure and certain water rights system to encourage development and settlement of the west, passed the Desert Land Act, Reclamation Acts, and other federal laws beginning in the mid-1800s. It was thus formally and officially recognized that rights to use water in the west would be governed by appropriation laws of the states.

English Rule of Absolute Ownership (Groundwater)

During the period when English courts were developing the natural flow riparian right doctrine, a few controversies arose concerning use of groundwater. Essentially, and without modern technology and knowledge, the courts in the 1800s presumed (even noting so in opinions) that water under the surface of the earth was mysterious and incapable of broad-based regulation. Accordingly, English cases held that because the landowner owned all materials associated with the land (center of earth below to the heavens above), including groundwater, the landowner could capture and use all the groundwater found under the surface, even if use of that water harmed the adjoining landowner. Texas continues to follow the doctrine of the "rule of capture" on ownership and use of groundwater.

American Rule of Reasonable Use (Groundwater)

Most early U.S. courts rejected the English rule of absolute ownership of groundwater and the perceived harsh results of that doctrine. Instead, American courts incorporated a "reasonableness" test when conflicts over groundwater use were presented. The Oklahoma Supreme Court in the 1936 case of Canada v. City of Shawnee specifically rejected the English rule of absolute ownership and instead adopted the American rule whereby a landowner's use of groundwater is allowed, even if that use adversely affects a neighbor, but only if the landowner's use is considered reasonable. One very important restriction of the American rule was also adopted by the Court in the Canada case (i.e., use of the groundwater off the premises from where it was pumped was per se unreasonable). Accordingly, under the American rule of reasonable use, Shawnee was prohibited from transporting groundwater from wells located in a farming area outside the city for use within the city.

Correlative Rights (Groundwater)

This water law doctrine is most associated with management and use of groundwater in California and is sometimes referred to as "strict proportional sharing." In a drought when water levels drop, all overlying landowners must equally decrease use so everyone might have some water.

Allocation (Groundwater)

A unique blend of some aspects of the reasonable use doctrine and the correlative rights doctrine was adopted in Oklahoma for use of groundwater, effective in 1973. The 1973 allocation doctrine is discussed in the "Groundwater Law" section.

Stream Water Law

Appropriation Statutes and Cases Before 1963

Just seven years after adoption of the 1890 property ownership statute mentioned previously, the Oklahoma Territorial Legislature adopted a comprehensive appropriation code for water use. The first section of that initial statutory appropriation law from 1897 declared more than a century ago that "the unappropriated waters of the ordinary flow or underflow of every running stream or flowing river and the storm or rain waters of every river or natural stream, canyon, ravine, depression or watershed… are hereby declared to be the property of the public and may be acquired for appropriation for the uses and purposes and in the manner as hereinafter provided."

This first comprehensive appropriation law contained specific beneficial uses for which water could be appropriated (irrigation, mining, milling, water works for cities and towns, and stock raising). It also included the statement that, as between appropriators, the first in time was the first in right. The 1897 statute went on to say that the ordinary flow or underflow could not be diverted to the prejudice of the rights of the riparian landowner without consent, except by condemnation. The law also stated that after an appropriation right has been established, it was unlawful for any person to divert or appropriate that water, except that landowners who abutted the stream could use the running water for domestic purposes (the first domestic use exemption).

In 1905, this comprehensive appropriation law was made even clearer by the Territorial Legislature by stating in the first section that "beneficial use shall be the basis, measure and limit to the right to the use of water," and that "priority in time shall give the better right." These two statements are repeated verbatim in the current stream water appropriation law of the State of Oklahoma; these two statements reflect the foundational pillars of the appropriation doctrine followed in virtually all western states.

Also as part of early Oklahoma law, the Oklahoma Territory Supreme Court issued an opinion in September 1907 that recognized the common law elements necessary to show that an appropriation right had been established: "[1] There must be the construction of ditches or channels for carrying the water; [2] the water must be diverted into the artificial channels and carried through them to the place to be used; [3] it must be actually applied to beneficial uses; and [4] he has the best right who is first in time."

Early statutes on appropriation required the filing of an application to the State Engineer before ditches, channels, or reservoirs were constructed. Permits to appropriate could be issued only after hydrologic studies were completed to indicate how much water could be appropriated. The lack of funding to conduct such studies precluded the issuance of permits for the most part, but hundreds of applications were filed. The priority date for the appropriation right under the law was the filing date of the application.

Although the Territorial Legislature and Supreme Court recognized the appropriation doctrine to regulate stream water use in Oklahoma Territory, Congress specified in the 1890 Organic Act that Indian Territory would follow the common law of the State of Arkansas, which recognized the riparian rights doctrine. Oklahoma Territory statutes and decisions by the Oklahoma Territory Supreme Court did not apply to Indian Territory. However, when Oklahoma Territory and Indian Territory merged through statehood in 1907, the Oklahoma Legislature adopted statutes on water ownership and appropriation that were virtually identical to Oklahoma Territory statutes. Regardless, the riparian doctrine survived as a result of several notable court cases.

Simultaneous Recognition of Appropriation and Riparian Rights

The basic provisions of the 1905 appropriation statute became the statutory law adopted by the State Legislature and remained virtually unchanged until 1963. As noted, the Oklahoma Supreme Court issued opinions relating to controversies between riparian landowners without regard to the appropriation statutes that had been on the books from 1905 through 1963. Complicating the issue, these Oklahoma court cases relied on the "reasonableness" of the riparian use despite the statutory provision in the property statute since 1890, which provided that the landowner abutting a stream can use water in a running stream "but cannot prevent the natural flow of the stream."

Irreconcilability of Appropriation and Riparian Doctrines

In the mid-1950s, with the increase in post-war population, economic development, and consequently, water demands, it became clear that Oklahoma's appropriation and riparian doctrines of water rights regulation were incompatible and irreconcilable. The riparian doctrine gives no credence to the date that others may have begun using water, and instead recognizes that a riparian landowner can initiate a use and take water out of the stream any time, preventing the flow to a water user downstream that began using water long before the riparian landowner began use. A riparian landowner who just began using water could even enjoin an upstream appropriator (who may have spent a considerable sum on infrastructure) from diverting water so it will flow downstream to the riparian lands. Thus, the certainty and security of appropriation rights, represented by a priority date and based on the volume of beneficial use, could be defeated by recognition of riparian rights to use water from the same water source.

A Water Study Committee created by the Oklahoma Legislature in 1955 reviewed and considered the implications of the irreconcilability of the appropriation doctrine and riparian doctrine. In 1957, the Oklahoma Legislature approved House Joint Resolution 502, drafted by the Water Study Committee, which adopted a State Water Policy. The policy set out fundamental recommendations concerning water use administration that remain in place today, more than 50 years later. Some of the fundamental recommendations from HJR 502 enacted into law include: (1) creation of the OWRB to oversee and administer water rights, (2) recognition that owners of land own diffused surface water and groundwater, (3) recognition that public waters flowing in definite streams should be subject to appropriation for the benefit of the public, and (4) recognition that domestic uses of water for land owners should be protected. The OWRB was created in 1957 during the same legislative session.

1963 Amendments to Reconcile Appropriation and Riparian Systems

In 1963, the Oklahoma Legislature implemented recommendations of HJR 507 to reconcile the incompatible stream water rights systems. A new appropriation law was passed, which reiterated that water flowing in a stream was public water subject to appropriation. The new law also specified that after 1963, all uses of water had to be authorized by permits to appropriate and that all uses of water before the 1963 law, whether the use was by riparian landowners or by non-riparian appropriators, could be recognized with a priority date through "vested rights" proceedings conducted by the OWRB. The law specifically listed seven categories of priorities for use that could be recognized.

One of the most important components of the new law was the specific recognition that domestic use by riparian landowners was exempt from any permit requirement, and that appropriation permits would be prohibited from interfering with domestic uses. In other words, the riparian right to an unquantified "reasonable use" was not abolished. The riparian right was instead simply limited to "domestic use," similar to the 1897 appropriation law. The phrase "domestic use" was also defined in the law to specifically include household uses, small gardens, orchards, and cattle watering.

By 1968, the "vested rights" proceedings had been conducted by the OWRB for all stream systems across the state except for the Grand River system (subject to the control of the GRDA). The OWRB began issuing permits to appropriate water from "definite streams."

Stream Water Law – Current Provisions

In 1972, the Stream Water Law was amended and is now codified in Oklahoma Statutes beginning at Section 105.1 of Title 82. Most of the fundamental components of the 1963 law (some of which can be found in the pre-statehood 1897 statutes) were retained. Some of the retained provisions include the right of eminent domain to access water, the right to use a watercourse to transport water, the authority for any domestic user or water right holder to file suit in district court over impairment of water rights (which suits can result in stream-wide adjudications), requirements about commencing and completing works, provisions about time for putting the water to beneficial use and loss of rights if authorized amounts are not put to use, and provisions on changes of rights and setting aside unappropriated water where the United States decides to build a reservoir. A definition section was also adopted, with one of the most important definitions discussed below.

"Definite Stream"

The 1972 law defined "definite stream" to mean "a watercourse in a definite, natural channel, with defined beds and banks, originating from a definite source or sources of supply. The stream may flow intermittently or at irregular intervals if that is characteristic of the sources of supply in the area." This definition is intended to clarify that diffused surface water is not stream water subject to appropriation. It should also be noted that most water in reservoirs, lakes, and ponds has long been considered water in a definite stream that is public water subject to appropriation. The Oklahoma Supreme Court confirmed that view for water in playa lakes.

"Domestic Use" Exemption

As noted, domestic use was defined by the 1972 law to include household uses, cattle watering, etc., which involve a de minimis amount of water. The law exempts domestic use from any permitting requirement. The law also allows a landowner to store two years' domestic use supply in a pond that may be constructed on a definite stream.

Procedural Requirements to Obtain Appropriation Permit

The Stream Water Law provides that any person who intends to acquire a water right in Oklahoma must file a permit application, which is considered for approval by OWRB members. The application must detail the applicant's plans to use the water. Information about the proposed location and method of diversion, capacity of pumps, pipes, valves, and other appurtenances must be provided, as well as the proposed place of use and details about the ultimate use. For example, an irrigator must list the possible crops and cropping patterns proposed and type of irrigation system (e.g., center pivot, flood, drip, etc.). A public water supplier must provide details about the water system to be constructed. Information about any proposed storage is necessary, such as use of a lake or pond. The filing of the application becomes the priority date if the application is approved and a permit issued.

OWRB staff typically assist applicants in filling out applications or in providing information that an applicant needs for processing the application. After the application is deemed complete by OWRB staff (i.e., the application contains sufficient information that if not contested can be approved by the OWRB), OWRB staff will instruct the applicant to issue public notice of the application. The statute requires that the notice of the application must contain essential facts about the application and must be published in a newspaper of general circulation in the county of the point of diversion and in the next county downstream. If the application is protested, the OWRB will schedule an administrative hearing before a hearing examiner. Note the diversion requirement is listed in the provision on notice. The common law of appropriation, recognized by the Oklahoma Supreme Court in 1907, required a physical diversion of water from the stream as an essential element to appropriate water. The law on notice indicates that a physical diversion requirement is still part of the law in Oklahoma.

For protested applications, the hearing examiner will gather facts, and then synthesize the facts and law into a proposed findings of fact and conclusions of law to be presented to the nine-member OWRB that meets monthly. As provided in the Administrative Procedures Act (APA) that governs the OWRB hearing process, the applicant and any protestants are provided an opportunity to present their arguments to the OWRB before the OWRB votes on whether to accept the hearing examiner's proposed order. Any party that is adversely affected by the OWRB's final order may seek review in a district court according to the APA.

In addition to regular appropriation permits that authorize year round use, the OWRB may issue seasonal permits that authorize use for specified time periods during the year and term permits that authorize use for a specified term. Seasonal and term permits may be issued even if the OWRB finds no unappropriated water available. "Provisional temporary" (PT) permits may be administratively issued without notice and hearing, but authorize use for no more than 90 days. These kinds of permits are often relied on by oil and gas companies for a source of water used in the drilling of wells.

Statutory Elements to Obtain an Appropriation Permit

The Stream Water Law not only sets out the process that must be followed by an applicant to obtain a permit to appropriate, but also specifies the items that must be shown before the OWRB can issue a permit to appropriate, as follows:

1. Whether there is unappropriated water available in the amount applied for. This element triggers the fundamental water accounting system implemented by most states that follow the appropriation doctrine. Amounts of water that are already appropriated and amounts assumed to be needed for domestic uses are subtracted from the estimated amounts of water that would flow down the stream naturally. The remaining amount is considered unappropriated water available.
2. Whether the applicant has a present or future need for the water and whether the proposed use is a beneficial use. This anti-speculation element is an extension of the foundational principle that beneficial use is the basis, measure, and limit of an appropriation right. This is the first of several provisions to ensure the applicant is not merely speculating on using water and helps avoid issuing paper rights that have the effect of impeding economic development by legitimate water users.
3. The proposed use does not interfere with domestic and existing appropriative uses. Because it is difficult to prove a negative as seemingly required by this language, OWRB rules allow an applicant to certify and agree to a permit condition that the applicant will not interfere with domestic uses and senior appropriations. The burden then shifts to a domestic user or senior appropriator to show that the use as proposed will interfere with their uses. The controverted matter may be resolved by the applicant agreeing to monitor and limit diversions as agreed upon by the parties.

Basin of Origin Protection

If the application is for transportation and use outside the stream system where the water originates (area of origin), the OWRB must determine that the proposed use will not interfere with existing or proposed beneficial uses within the area of origin in addition to making the determinations previously discussed. The law goes on to provide that pending applications to use water within the area of origin will be considered before an application to use water outside the area of origin, which is a leap-frog provision that allows in-basin applications to be considered out of the usual priority date order. The OWRB must also review the uses and needs in the area of origin at least every five years to ensure accurate information. Permits to use water outside the area of origin cannot be reduced based on the five-year reviews.

Out-of-State Use

In 2009, the Legislature adopted House Bill 1483. This bill added a new provision and amended a provision of the existing Stream Water Use Law to address out-of-state use of water. The new provision reiterated the importance of the need to comply with Oklahoma's four interstate stream compacts, and contained a provision that no permit to use water out of state would authorize use of water apportioned to Oklahoma by a compact unless the permit was approved by the Legislature. HB 1483 also required that before the OWRB could issue a permit to appropriate for out-of-state use, the OWRB must evaluate whether the water requested for out-of-state use could feasibly be used to alleviate shortages within the state. The applicant must designate an in-state agent for service of process and must agree to comply with any Oklahoma conditions that may conflict with conditions in the other state. Permits for out-of-state use would be subject to additional conditions based on a required 10-year review of such permits.

Beneficial Use Requirements and Forfeitures

Even though the OWRB must determine whether a beneficial use is proposed before a permit can be issued in the first place, that is not the end of the beneficial use inquiry. As noted earlier, one of the foundational principles on which the appropriation doctrine is based and expressly stated in the Stream Water Use Law is that beneficial use is the basis, measure and limit of an appropriation right. Due diligence is required to initially put the water to use and to continue using the water to retain the right. The appropriation right, when it becomes vested after initial use, is considered a vested right that cannot be taken without just compensation. However, it is a conditional vested right, conditioned on compliance with the requirements of the law and conditioned on continued beneficial use. If beneficial use does not begin as required, or if beneficial use stops after the initial use, the Stream Water Use law provides that the water right is lost (forfeited to the extent of nonuse), and the appropriation right holder must acknowledge and accept the law.

Specifically, the Stream Water Use Law provides that works to place water to use must be initiated within two years after the permit is issued (unless the OWRB approves an extension). The law then provides that the permit holder gets seven years after permit issuance in which to put the full amount of water to use, unless the OWRB approves a Schedule of Use based on an extended time frame that is needed to put the full amount to use. Municipalities often seek approval of a Schedule of Use because it may take up to 50 years to put all the water to use based upon population projections. The municipality must have assurance through the authority of an appropriation right that the water can be used in the future to generate revenues to pay for the project over the extended period. The Stream Water Use law provides that after use begins, the amount used becomes vested and that vested amount must be used for the authorized purpose within seven continuous year periods thereafter. Amounts not used are subject to automatic forfeiture. The OWRB is authorized to hold hearings to provide an opportunity for the water right holder to demonstrate cause as to why the water right should not be declared forfeited.

Oklahoma Appropriation Law and Franco-American Charolaise

As discussed previously, the Oklahoma Supreme Court ruled in a 1993 opinion that Oklahoma still retains riparian rights to a reasonable use instead of the natural flow riparian rights doctrine. The major significance of the Franco case is that it completely modified the appropriation doctrine law approved by the Legislature in 1963 that was enacted to reconcile the incompatible riparian and appropriation doctrines.

In their 5-to-4 decision, the Court ruled that if the 1963 appropriation law was interpreted to abolish riparian rights to a reasonable use, then the law would be considered an unconstitutional taking of vested rights of riparian landowners. The Court explained that the riparian right to a reasonable use was a "vested right" because courts (common law) had recognized the existence of such rights. Apparently, but without much explanation, the court concluded that the riparian right came into existence at the time that private ownership of the tract of riparian land came into being. In some areas of the state, private property ownership came into being upon the issuance of the federal government patent, or when a patent was issued by one of the Five Tribes, or when the State of Oklahoma issued the patent. The Court also explained that the riparian landowner could initiate use of water at any time, and that the facts and circumstances prevailing at the time of a controversy would be subject to a court inquiry as to whether such use by the riparian landowner was in fact "reasonable." If another riparian landowner initiated a new use, or if the first landowner changed use, or if a person wanted to obtain an appropriation permit from the OWRB, the Court explained that a "reasonableness" inquiry would have to be made by a court before the OWRB could move forward on the appropriation permit application. This is so, the Court said, because the riparian use that is determined "reasonable" would have to be subtracted from the amount of water available for appropriation.

What resulted is the Court's creation of a super-priority for riparian uses that are determined to be "reasonable." Within a few short months after the Court issued its Franco opinion in early 1993, the Oklahoma Legislature responded to the Court and its criticism that the 1963 law did not expressly extinguish the common law of riparian right to a reasonable use. The Legislature accordingly adopted a new section of the Stream Water Use law to expressly provide that the only riparian rights recognized are the limited riparian rights to domestic use plus the previous riparian uses that were determined to be "vested rights" to appropriate in the proceedings conducted as required by the 1963 law. There has been no final court determination as to whether the 1993 statute is effective. As a result, a cloud on appropriation rights remains.

Groundwater Law

The law on groundwater use regulation has a shorter history than the counterpart laws on stream water use. Recall that the owner of the land owns water under the surface of the earth, but not forming a definite stream. There are no known underground definite streams in Oklahoma. The Oklahoma Supreme Court declared decades ago that all water under the surface of the earth is presumed to be percolating groundwater and not water in a definite stream.

American Rule of Reasonable Use Common Law

The 1936 Oklahoma Supreme Court case, which declared that all water under the surface of the earth is percolating groundwater, is the same case that declared the American rule of reasonable use (as opposed to the English rule of absolute ownership) would be the common law followed in Oklahoma. However, as noted previously, a principle of the American rule of reasonable use is that water pumped from the premises had to be used on the premises, and that use off the premises is per se unreasonable, thus precluding municipalities and rural water districts from using groundwater.

1949 Groundwater Appropriation Statute

The first statutory law to regulate groundwater was adopted in 1949 and replaced the common law American rule of reasonable use. The 1949 law imposed the appropriation doctrine with provisions on beneficial use and that priority in time gives the better right. The 1949 appropriation law did not directly tie use of groundwater with ownership of land. That law was soon deemed ineffective and too restrictive because groundwater use in "critical groundwater areas" was limited to the "safe annual yield" (average recharge rate). Such a restriction would have prohibited development and use of groundwater from the prolific Ogallala aquifer in the Panhandle and northwestern Oklahoma because there is relatively little recharge of groundwater in this arid region.

1973 Oklahoma Groundwater Law Allocation System

The 1949 law was completely replaced by the current Oklahoma Groundwater Law that became effective in 1973. The 1973 allocation law makes a direct connection to land ownership and ownership of groundwater (as declared by law since 1890) by tying the amount of groundwater that can be allocated by a permit to the number of surface acres that overlie the groundwater basin owned by the land owner. The Oklahoma Supreme Court determined that this new groundwater law, contrary to its later decision about the Stream Water Use law, did not result in an unconstitutional taking of the common law right to a reasonable use but was instead an authorized exercise of the police power of the state. The Oklahoma Supreme Court also determined that the off-premises restriction of the American rule of reasonable use no longer applied. The fundamental provisions of the 1973 law are as follows.

Definition Of "Groundwater"

Groundwater means "fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut bank of any definite stream." The phrase "outside the cut bank of any definite stream" was intentionally added in a 1967 amendment to the previous law to correspond to the definition of "definite stream" found in the Stream Water Use law. The addition of this phrase in the statute was significant and ensured that water under the surface in the alluvium sands and gravels (that are found along most rivers and streams in the state) is "groundwater" that can be claimed as water "owned" by the overlying landowner instead of being "public water" subject to appropriation and use by others. Previous to this definition change, the 1897 and 1905 Territorial Statutes on the appropriation doctrine declared that the "underflow" of streams was considered property of the state (i.e., public water subject to appropriation). The underflow was understood to include water in stream alluvium areas. Later court adjudications of rights to stream systems from the 1930s confirmed and decreed that volumes of water pumped from "wells in the alluvium" along with diversions of water from the stream had been appropriated by the claimants. Whether and to what extent issues relating to conjunctive use or integrated use management could be addressed by revising the definitions of "definite stream" and "groundwater" could be the subject of further discussion.

Maximum Annual Yield and Equal Proportionate Part or Share

One of the most significant provisions of the 1973 allocation law directs the OWRB to determine the maximum annual yield (MAY) for each groundwater basin in the state. The law requires the OWRB to conduct hydrologic studies, or accept studies of other agencies like the U.S. Geological Survey, as a first step in the process. With this hydrologic information, the OWRB must make a "tentative determination" of the MAY based on five factors specified in the law. The law then requires the OWRB to make the hydrologic surveys available to the public and conduct a public hearing on the tentative determination in the basin area. Evidence in support of or opposition to the tentative determination is received, and then the OWRB must make a final determination of the MAY to be allocated to each acre of land that overlies the basin. The amount to be allocated to each acre is known as the equal proportionate share (EPS) or part of the MAY.

The law goes on to provide that after the MAY is determined, the OWRB can issue "regular" permits that allocate the EPS for each acre of land dedicated to the permit application. The law specifically states that a regular permit "shall allocate to the applicant the proportionate part of the maximum annual yield of the basin or subbasin. The proportionate part shall be that percentage of the total annual yield of the basin or subbasin, previously determined to be the maximum annual yield as provided in Section 1020.5 of this title, which is equal to the percentage of the land overlying the fresh groundwater basin or subbasin which the applicant owns or leases and which is dedicated to the application."

It is important to note that the "allocation" of groundwater occurs with the issuance of the permit, not at the time the MAY is determined. This view is necessary in light of the provision in the law that requires updates of hydrologic studies at least every 20 years, and the law which provides that in subsequent basin hearings to update the MAY, the OWRB may "increase the amount of water allocated but shall not decrease the amount of water allocated." If the allocation for each landowner occurs when the MAY is first determined, the OWRB could never decrease the MAY even if updated studies show that too much water could be withdrawn from the basin.

"Temporary" Permits (Before MAY Determination)

The 1973 Oklahoma Groundwater Law anticipated that in transitioning to the new allocation system, it would take some time for the OWRB to conduct hydrologic surveys and determine the MAY for all groundwater basins in the state. Accordingly, the Legislature provided authority for the OWRB to issue "temporary" permits to use groundwater before the determination of the MAY for a basin. The law provides that "the water allocated by a temporary permit shall not be less than two (2) acre-feet annually for each acre of land owned or leased by the applicant." These kinds of permits are "revalidated" annually, with the request to revalidate being part of the annual water use report that is required to be filed each year with the OWRB. Revalidations can be protested, but only changes of conditions can be presented at the hearing on revalidation. In light of the high costs and limited budgets, studies and determinations of the MAY have not been completed for many basins in the state. Accordingly, some "temporary" permits issued in 1973 are still being revalidated after more than 35 years.

Procedural Requirements to Obtain a Permit to Use Groundwater

Similar to the procedures followed to obtain a permit to use stream water, the Oklahoma Groundwater Law requires the filing of an application before groundwater is used (the law allows test wells to be drilled before an application is filed, however). Staff typically provides assistance to applicants to fill out applications. The application requires submittal information about ownership (or leasehold or other interest in the land), well locations, type of use and place of use. After the application is deemed complete, staff then instructs the applicant to publish notice of the application in a newspaper of general circulation in the county where the wells and land are located. Unlike a stream water permit application, certified mail notice must also be given to owners of land located within a quarter mile of a proposed or existing well that the applicant intends to use. If the application is protested, a hearing examiner will schedule a hearing, and the parties have the opportunity to provide evidence in support of, or opposition to, the application. The hearing examiner then provides proposed findings, conclusions and order to the nine-member OWRB to be considered at their monthly meeting where the parties may present oral arguments. The final order of the OWRB is subject to review in district court under the APA.

In addition to "regular" and "temporary" permits, the OWRB is also authorized to issue a 6-month "special" permit for quantities of water greater than can be allocated by a regular or temporary permit. Like the Stream Water Use law, "provisional temporary" (PT) permits may be administratively granted without notice and hearing, but are effective for no more than 90 days. Most oil and gas companies rely on PT permits for water needed for their short term well drilling activities.

Statutory Elements to Obtain a Permit

Whether a "regular" or "temporary" permit is sought, the law provides that certain matters must be determined by the OWRB before the permit can be issued, including:

1. Whether the lands owned or leased by the applicant overlie a fresh groundwater basin. Virtually all lands in Oklahoma overlie some groundwater basin, whether major or minor, so this is rarely an issue. However, the issue of ownership or leasehold interest is sometimes in controversy. The OWRB is not a court of general jurisdiction to adjudicate title to lands and simply relies on photocopies of deeds or leases to confirm the applicant's interest in the land acreage described in the application. If a protestant disputes ownership, the OWRB stops the proceedings to allow the parties to resolve the dispute in a district court before the OWRB will move forward.
2. The use proposed is a beneficial use. The law does not define beneficial use, but OWRB rules define "beneficial use" as the quantity of groundwater when reasonable intelligence and reasonable diligence are exercised in its application to a lawful purpose and as is economically necessary for that purpose. Examples include municipal, industrial, agriculture, irrigation, recreation, fish and wildlife uses.
3. Waste as specified by law will not occur. Section 1020.15 enumerates 10 activities that constitute "waste." One of these items is the permitting or causing the pollution of a fresh water strata or basins through any act. This provision became the subject of significant controversy when oil and gas companies began using groundwater in secondary and tertiary recovery projects. This provision was revised in 2001 to preclude the OWRB from making a determination about waste by pollution relating to activities regulated by the Department of Environmental Quality (e.g. municipal and industrial wastewater discharging) or the Department of Agriculture, Food and Forestry (e.g. confined animal feeding operations).

If these three items are shown in favor of an applicant, the law provides that the OWRB "shall" issue the permit (i.e., issuance is mandatory, not discretionary).

Well Spacing, Location Exceptions and Other Conditions

The Oklahoma Groundwater Law authorizes the OWRB to establish well spacing (i.e. the distance between water wells) and location exceptions. However, the statute was interpreted by the Attorney General as limiting the OWRB's authority only for those basins where the MAY has been determined (and regular permits are issued). A requirement to have wells spaced at some distance one from another is a method to reduce or avoid pumping interference that can be caused when wells are pumping at the same time (referred to as the "cone of depression effect"). Well pumping interference can be affected in ways other than the distance that the wells are spaced apart. The pumping capacity of the well, the number of hours in a day that the well is pumping, the depth of perforations of the well, and the level of sealing the well can all play a part in the extent of interference. Separate from the well spacing and location exception sections of the law, the law provides the Board shall specify the location of the permitted well or wells "and other terms and conditions as specified by the Board, including, but not limited to, the rate of withdrawal, the level of perforating and the level of sealing the well." Accordingly, the Board can address well interference issues that may be raised in basins for which the MAY has not been determined, although such matters require a significant amount of information and efforts to conduct computer modeling to predict effects in order to impose proper terms and conditions.

Metering

The groundwater law authorizes the OWRB to require meters to be placed on wells, but only in a rare instance where a majority of landowners overlying a basin request such metering. With hundreds of thousands of landowners overlying each basin, this provision has never been activated. On occasion, an applicant will voluntarily agree to install a meter to address a concern of a protestant. Public water supply wells are required to be metered by Oklahoma Department of Environmental Quality rules.

Platted Lands and Municipal Use of Groundwater

The Oklahoma Groundwater Law allows municipalities to regulate domestic and industrial wells within their corporate limits. This provision has been interpreted to mean that municipalities cannot prohibit (as opposed to regulate) landowners from using groundwater owned by the landowners. The law also provides that municipalities may use groundwater allocated to platted lands within their corporate limits on the condition that permits are obtained from the OWRB, the wells are located within 600 feet of the corporate boundaries, and the wells are located on platted land.

Domestic Use Exemption

Like the Stream Water Use law, the Oklahoma Groundwater Law exempts domestic use from the permitting requirements of the law. However, the exemption specifically provides that "wells for domestic use are subject to sanctions against waste." In other words, a well used for domestic use can nevertheless be subject to an order of the OWRB to plug it if the well (due to faulty casing, etc.) is causing pollution of the groundwater.

Sensitive Sole Source Groundwater Basin and Conjunctive Management

In 2003, as a result of a proposal to pump groundwater from the Arbuckle-Simpson Groundwater Basin to supply municipalities in central Oklahoma, the Legislature enacted Senate Bill 288 to amend the Oklahoma Groundwater Law in two significant ways. First, for any "sensitive sole source groundwater basin" (defined as a groundwater basin any part of which has been designated by the EPA as a "sole source aquifer" plus a 5-mile buffer zone), a moratorium was imposed on use of groundwater away from the basin. The moratorium is in effect until the OWRB determines a MAY that would ensure that permits issued to pump water from such a basin "will not reduce the natural flow of water" from basin area streams or springs. SB 288 also added a new requirement before the OWRB could issue a permit to pump groundwater from such a basin (i.e., whether "the proposed use is not likely to degrade or interfere" with the flow of water from basin area streams and springs).

Since the complete separation of laws on the use of stream water and use of groundwater, clarified with the 1967 amendment to the definition of "groundwater" to include water in the alluvium of streams, SB 288 is the first statutory recognition that the use of one category of water (groundwater) can affect the other category of water (stream water) and that a conjunctive or integrated management approach is needed in certain instances.

Diffused Surface Water, Flooding and Floodplain Management

As mentioned, diffused surface water, like groundwater, is owned by the land owner. While there are no state statutes governing the consumptive use of diffused surface water, there are several court cases and principles that can affect how a landowner can manage diffused surface water. In Oklahoma, the "common enemy doctrine" that allows the diversion of water onto lands of another to prevent damage to the diverter's land is modified by the "rule of reason" principle that any such diversion must be done reasonably and with due regard to the rights of others.

Another body of law and regulations that may apply to diffused surface water includes the National Flood Insurance Program (NFIP) and the Oklahoma Floodplain Management Act. Under the NFIP, Federal Emergency Management Agency regulations and state law, counties and municipalities that choose to participate in the program must establish a local floodplain management program that restricts development in floodplains and requires development permits. Besides reducing life and property losses, the benefit to the local communities is that their citizens can obtain low cost, subsidized flood insurance on property within participating communities. Federally backed mortgages and most private mortgage companies will not loan money on property in a floodplain unless flood insurance is obtained. Non-subsidized flood insurance premiums for property that is not in a participating community can be extremely costly and even preclude property transfers where a mortgage is involved.

Atmospheric Water and Weather Modification

The OWRB administers the Oklahoma Weather Modification Act found in 82 O.S. §1087.1 and following. That act authorizes the OWRB to issue licenses to operators and permits for specific operations for weather modification activities. Weather modification includes two major aspects: (1) rainfall enhancement, and (2) hail suppression. While rainfall enhancement can theoretically result in significant positive benefits for large areas of agriculture production, hail suppression can result in significant savings for property insurance companies. There are at least three notable problems involved in implementing a weather modification project: (1) significant start up costs with high cost of airplanes and pilots on standby for weeks and months to be ready to take advantage of appropriate weather conditions to seed clouds; (2) significant potential liabilities, and resulting high insurance costs, from hundreds or thousands of property owners that may claim too much rainfall was created that caused flooding and damages and from property owners that claim hail was increased instead of decreased; and (3) insufficient studies that confirm whether cloud seeding works and provides benefits, at least to the degree necessary to justify the significant costs. The last project that operated in the state was funded by Rainy Day Funds approved by the Legislature during the Keating Administration.

Interstate Stream Water Compacts

There are three methods to address disputes and controversies about water flowing between two or more states: (1) equitable apportionment where the U.S. Supreme Court in expensive long-term litigation must decide the equities that exist to divide the water; (2) direct Congressional apportionment, where Congress divides the water as set forth in a federal statute; and (3) interstate agreed apportionment by a negotiated compact that is approved by Congress.

States have the most input on how interstate water is divided by negotiating a compact agreement that apportions the water. Under the U.S. Constitution, no State shall without the consent of Congress, enter into any agreement or Compact with another State. The State of Oklahoma has chosen the compact method to apportion virtually all water that flows into or out of the State of Oklahoma. There are four compacts to which Oklahoma is a party: Canadian River Compact with New Mexico and Texas (1950), Kansas-Oklahoma Arkansas River Compact with Kansas (1965), Arkansas-Oklahoma Arkansas River Compact with Arkansas (1970); and Red River Compact with Arkansas, Louisiana and Texas (1980).

By virtue of the Constitutional requirement for the consent of Congress, compacts are enacted in federal statutes, as well as in the statutes of each of the agreeing states. Among other things, interstate stream compacts apportion the waters in major streams and their tributaries between or among the agreeing states. These compacts also establish interstate agencies known as Compact Commissions, consisting of one or more commissioners from each state, plus one or more non-voting federal commissioners. The Compact Commissions meet annually (at rotating locations in the member states) to receive reports regarding stream flows, amount of water stored in reservoirs, and water quality, and to conduct other business to administer the compact provisions. Compact Commissions are assisted by several standing committees staffed by personnel of appropriate member state agencies. Such committees usually include a budget committee, engineering committee, and legal committee. The Arkansas-Oklahoma Arkansas River Compact Commission and the Red River Compact Commission also include a standing environmental committee. Usually compact commissions are unable to take significant action in controversial matters because unanimous votes are required.

Federal Rights

Navigation, Commerce and Supremacy

The authority of the U.S. government to regulate navigation has its roots from the common law of England, which recognized that the sovereign King controlled the seas and submerged lands near the shore to control port placement and operations. Although the ownership of the beds of rivers was later determined to be held by the States, the U.S. Constitution gave to Congress the authority to regulate commerce among the States. Because waterways were used to transport goods among the States early on, Congress began to enact laws about navigation that affected the use of water. Therefore, while States may claim ownership of the beds of rivers based on the equal footing doctrine, the Commerce clause established a "navigation servitude" on all lands and on all state-created water rights allowing Congress to enact laws that have the effect of overriding state laws on water use. This "navigation servitude" is described to exist on lands and water up to the "ordinary high water mark" of navigable streams.

The Commerce Clause of the U.S. Constitution has also been interpreted to allow Congress to regulate water used for hydropower purposes. Accordingly, the U.S. Supreme Court ruled that a State cannot usurp the Federal Power Act and prohibit a hydropower project from operating by denying a water use permit to the operator. The U.S. Supreme Court has recognized, however, that Congress, through the Clean Water Act and its Section 401 provision about state water quality certifications of federal permits and licenses, does provide the States with limited "veto" power over hydroelectric projects if the state withholds a water quality certification for the federal license.

Another exception to the navigation and hydropower supreme authority of the federal government was created by Congress. The O'Mahoney-Milliken Amendment to the Flood Control Act of 1944 says that use of water for navigation or hydropower in states like Oklahoma cannot conflict with "beneficial consumptive uses" in those states. In other words, if a municipality or irrigator with a state water right diverts water upstream from a navigation channel or upstream from a hydropower facility, the federal government cannot prevent the municipality or irrigator from using the water.

Proprietary Rights of the United States and Federal Reserved Rights

Article 4, Section 3, Clause 2 of the U.S. Constitution says that Congress shall have the power to make rules and regulations respecting property belonging to the U.S. Under this clause, Congress or Presidents through executive orders have created National Parks, National Monuments, National Recreation Areas, National Forests, National Wildlife Refuges, and National Fish Hatcheries from public lands or from lands otherwise acquired by the federal government. If water is needed to fulfill the primary purposes of those federal enclaves, courts have approved federal reserved rights claims to use such waters without the need for the federal government to obtain state issued permits. Somewhat like Indian water rights, the federal government can make the claim for a reserved right even if the federal law or executive order did not mention water. The priority date for federal reserved right claim is the date of the federal law or executive order creating the federal enclave. The federal reserved right is then administered alongside other state-issued appropriation rights in priority order.

Indian & Federal Reserved Water Rights

The concept of federal reserved rights, including water rights afforded to Oklahoma's Indian Tribes, largely originates in the Winters Doctrine, derived from the Winters v. U.S. federal court decision.

In the early 1830s, the U.S. entered into treaties with officials of five southeastern Tribes—the Cherokee, Muscogee (Creek), Choctaw, Chickasaw and Seminole Nations—pursuant to which those Tribes exchanged their homelands in Georgia, North Carolina, Tennessee, Mississippi, Alabama and Florida for lands in what would become the State of Oklahoma. What resulted was the forced migration of citizens of these Tribes, referred to as the Trails of Tears. Following the Civil War, similar treaties were entered into with additional Tribes that exchanged their lands for lands in Oklahoma.

Several areas in western Oklahoma were reserved for various Indian Tribes, but most of that land was allotted (i.e., transferred out of tribal ownership) to individuals before statehood. In the eastern portion of Oklahoma ("Indian Territory" prior to statehood), several large areas of land were granted to Indian Tribes by the federal government. Today, Oklahoma is home to 39 Tribes, and all continue to exercise their inherent authority established through treaties with the federal government.

In 1908, the U.S. Supreme Court declared in the Winters case that when the federal government reserved lands from the public domain for the nation's Indian populations, sufficient waters were also reserved, by implication, to allow Indian citizens to live on those lands. Despite this landmark ruling, some uncertainty exists concerning original tribal ownership of appurtenant waters and rights to the use of water within original tribal boundaries.

Although the question has not been fully litigated, Oklahoma Tribes have long claimed Winters rights. The Five Tribes, who received their lands in fee simple, make the additional or alternative claim that their treaties with the U.S. provide an even stronger claim. Federal judicial rules of treaty construction—that treaties with Tribes are to be interpreted as the Indians would have understood them, that ambiguities in Indian treaties are to be resolved in the Tribes' favor, and that treaties are to be liberally construed in favor of the Indians—tend to favor the tribal position. Another key question that remains unresolved is when treaty-based water rights are recognized to exist versus when they were possibly abrogated.

Federal rules concerning tribal civil regulatory jurisdiction, virtually all of which have been judicially created, are difficult to apply. The prevailing standard for tribal civil jurisdiction over non-Indians, for example, provides that Tribes can exercise such jurisdiction (at least on non-Indian-owned fee lands) only if the non- Indian is engaged in a consensual commercial relationship with the Tribe or if the acts of the non-Indian "threaten, or have some direct effect upon, the political integrity, economic security, or health or welfare of the Tribe." The ambiguities in this standard often lead to uncertainty as to which sovereign has the authority to regulate.

These lingering uncertainties, together with the formidable costs and potential complexity of litigation, have resulted in the State of Oklahoma and Tribes so far refraining from pressing judicial claims to ownership of, or jurisdiction over, water. Uncertainty, however, inhibits economic growth and complicates both protection of the environment and the responsible use of natural resources.

States and Tribes, as well as Tribes and the federal government, have addressed both jurisdictional and rights ambiguities by cooperative resolution, often in the form of a compact. Oklahoma has been a national leader in compacting to resolve uncertainty in other civil jurisdictional areas, including car tags and tobacco taxes, and that experience could prove helpful should the state decide to resolve water jurisdictional issues through negotiation. Negotiation would also allow the state and Tribes, rather than the judicial branch, to assume the primary role in addressing tribal sovereignty and associated water rights claims.

Water Quality and Pollution Control

The quality of surface and groundwaters in Oklahoma is of significant importance to the state's general public health and prosperity. Water ownership and rights do not include the right to pollute or degrade fresh water resources. Numerous agencies and organizations have been afforded responsibilities related to the enforcement of state and federal pollution laws. Specifically, the Oklahoma Department of Environmental Quality oversees the majority of the state's environmental protection and management programs. In addition, potentially harmful pollutants from both point and nonpoint sources are closely monitored by numerous entities to ensure that Oklahoma's rivers, streams and lakes receive at least adequate protection.

While the state originally passed laws to curb water pollution in the 1920s, it was through passage of the 1955 Pollution Remedies Act that Oklahoma made monumental strides toward public health and environmental protection. That law, which was more fully implemented with passage of the federal Clean Water Act in 1977, required regulation of discharges to state waters, provided for the protection of certain beneficial uses of stream water, and spawned adoption of Oklahoma's first standards for water quality in 1968.

Today, municipalities and industries must acquire wastewater discharge permits and adequately treat their wastewaters prior to release to ensure that the quality of receiving waters is not impaired. Oklahoma Water Quality Standards (OWQS), promulgated as rules by the OWRB and reviewed at least every three years, are the cornerstone of the state's water quality regulation. Standards serve to enhance water quality, protect beneficial uses and aid in the prevention, control and abatement of water pollution. In particular, standards are critical to the development of water quality-based discharge permits that specify treatment levels required of industrial and municipal wastewaters.

The designation and protection of beneficial uses—similar in concept, though separate from the strategy utilized in state water management and use programs—is vital to implementation of water quality standards. Currently recognized beneficial uses for the Water Quality Standards program (not to be confused with beneficial use requirements relating to water use) include water supply, fish and wildlife propagation, agriculture, industrial and municipal cooling water, recreation, aesthetics, navigation and hydropower. Physical, chemical and biological data on Oklahoma's rivers, streams and lakes are used to ascertain the condition of individual waters, determine appropriate present and future beneficial uses, and thus set realistic water quality standards to protect those invaluable resources. Through assignment of as many beneficial uses as are attainable, standards assure that existing water quality is not unduly impacted. Narrative and numerical criteria set forth in the OWQS are used by regulating state agencies to ensure attainment of beneficial uses and limit waste and pollution of state waters. All designated uses receive water quality protection because each use has its unique environmental and economic importance to Oklahoma. Although all of Oklahoma's surface waters receive protection through the OWQS, specific protection is afforded to approximately 27,000 stream and river miles and 650,000 lake surface acres. Beneficial uses designations have also been assigned to the state's major groundwater basins.

Through the efforts of numerous agencies and organizations, Oklahoma has made tremendous strides in limiting pollution from point sources, including municipal and industrial stormwaters. Similarly, the state has made great progress in minimizing impacts from nonpoint sources, such as agricultural operations, silviculture, urban areas, and various other nonpoint source-related activities. Efforts have been undertaken to encourage owners and operators of lands to adopt practices that minimize the contributions of nonpoint source pollutants to state waters. However, while these efforts have met with some success, water quality degradation continues to occur in many state waterbodies.

A major ongoing state effort to address pollution reduction is development and implementation of the "whole basin planning approach." This holistic strategy, which takes into account all threats to human health and ecological integrity within the watershed, places greater emphasis on all aspects of water quality, including chemical quality (toxic and conventional pollutants), physical quality (such as temperature, flow and circulation), habitat quality (such as channel morphology, composition and health of biotic communities) and biodiversity (i.e., species number and range). Using this information, flexible mitigation strategies for a specific watershed can be developed to address problem areas in a prioritized, more cost-efficient fashion.

The current manner in which state and federal agencies approach water quality regulation in Oklahoma has been greatly affected by passage of House Bill 2227, a measure passed in 1993 to mend the state's fragmented environmental regulatory structure. Through realignment of the responsibilities of eight agencies into one primary agency, the Oklahoma Department of Environmental Quality (ODEQ), the goal of HB 2227 was to eliminate the jurisdictional overlap and duplication of effort of state environmental agencies, provide for consistency of regulation between agencies, and improve the way in which citizen pollution complaints are addressed.

Specifically, HB 2227 consolidated air quality, solid and hazardous waste, and certain water quality functions into the ODEQ and established jurisdictional powers among state environmental support agencies. The measure also created an all-citizen rulemaking and appellate board for complaint, permit, and penalty matters. Other agencies with authority to manage and regulate activities that can impact water quality are in the list of defined "state environmental agencies" that include Oklahoma Department of Environmental Quality; Oklahoma Water Resources Board; Oklahoma Department of Agriculture, Food and Forestry; Oklahoma Corporation Commission; Oklahoma Conservation Commission; Oklahoma Department of Mines; Oklahoma Department of Public Safety; and Oklahoma Department of Labor.

State Water Agencies

There are many state and federal agencies and institutions involved in water-related matters in Oklahoma. Presented below is a list of those that possess major responsibilities in the regulation or management of Oklahoma's water resources.

The **Oklahoma Department of Agriculture, Food and Forestry** enforces rules relating to the state's agricultural industry. The agency has specific duties and responsibilities in the areas of pesticide use, storage, registration and application; fertilizer use and storage; confined animal feeding operations; and forestry operations.

The **Oklahoma Conservation Commission** develops and administers programs to control and prevent soil erosion; prevent floodwater and sediment damage; reduce nonpoint source pollution; promote implementation of Geographic Information System (GIS) technology in Oklahoma; protect state wetlands; and further the conservation, development and utilization of the state's renewable resources. In cooperation with Oklahoma's 87 conservation districts, the agency is involved in land use planning, reclamation of abandoned mine lands, water quality monitoring and in the overall conservation of soil, water, wildlife and forestry resources. With assistance from the USDA Watershed Program, Oklahoma Conservation Districts, designated as local watershed project sponsors, have constructed 2,105 upstream flood control dams in 64 counties.

The **Oklahoma Corporation Commission** regulates oil and gas activities in the state to prevent pollution of Oklahoma's surface and groundwater resources. The Commission has exclusive jurisdiction over salt water, mineral brines, waste oil, and other deleterious substances produced from, obtained or used in connection with the drilling, development, production and processing of oil and gas. The Commission also regulates transportation and transmission companies, public utilities, motor carriers, pipeline safety and for-profit water corporations.

The **Office of the Secretary of the Environment** is the recipient and administrator of Federal Clean Water Act funds, coordinates pollution control activities to avoid duplication of effort, acts on behalf of the public as trustee for natural resources, and performs other duties and powers as may be assigned by the Governor. This Office is responsible for overseeing and coordinating activities of a number of state environmental agencies including the Oklahoma Water Resources Board, the Department of Environmental Quality and the Department of Wildlife Conservation.

The **Oklahoma Department of Environmental Quality** has jurisdiction over a number of water-related environmental areas, including treatment and discharge of industrial and municipal wastewaters and stormwaters; nonpoint source discharges and pollution (excluding those associated with agricultural or oil and gas related activities); public and private water supplies; underground injection control (excluding brine recovery, saltwater disposal or secondary/tertiary oil recovery); fresh water wellhead protection; enforcement of Oklahoma's Water Quality Standards; and development and update of the state's Water Quality Management Plan. In addition, the ODEQ has jurisdiction over air quality, hazardous and solid waste, radioactive waste, Superfund program activities and emergency response.

The **Grand River Dam Authority**, established by the State Legislature in 1935, is responsible for administering water resources in the Grand River Basin, including portions of 24 counties in northeast Oklahoma. Expressly, the agency is a public corporation created to control, store, preserve and distribute waters of the Grand River and its tributaries for any useful purpose. The entity is self-sustaining with revenue derived from the sale of power and water. Instead of actual appropriation of waters, the agency enters into repayment contracts for the use of surface water resources in the basin. Groundwater use in the basin remains under jurisdiction of the OWRB. In addition to general control and management of river/tributary waters and hydropower projects at Grand Lake and Lake Hudson, GRDA operates and maintains an integrated electric transmission system, including some 2,090 miles of line and related switching stations and transformer substations.

The **Oklahoma Department of Mines** is the environmental regulatory authority empowered to execute, enforce and implement provisions of state and federally mandated programs in the area of health, safety, mining and land reclamation practices associated with surface and subsurface mining.

The **Oklahoma Scenic Rivers Commission** fosters programs to develop and protect the state's scenic river areas and adjacent lands.

The **Oklahoma Department of Tourism and Recreation** promotes tourism and recreation in the state and develops, operates and maintains state parks, recreation areas and lodges.

The **Oklahoma Department of Transportation** is the coordinating agency for the state's transportation systems, including the McClellan-Kerr Arkansas River Navigation System. Under the agency's jurisdiction are the Port Authority and Oklahoma Waterways Advisory Board.

The **Oklahoma Water Resources Board** promulgates and adopts water quality standards and related implementation documents for the state as well as directs programs to assess and improve lake water quality. The agency also administers state water quantity laws through the issuance of stream and groundwater permits; investigates stream and groundwater resources; approves and assists irrigation district organization; administers the state dam safety program; supervises state weather modification activities; establishes water well construction standards; and licenses water well drillers. The OWRB also administers the Financial Assistance Program for water/wastewater projects; coordinates the National Flood Insurance Program in Oklahoma; negotiates and administers interstate stream compacts; and updates the state water plan.

The **Oklahoma Department of Wildlife Conservation** enforces state fishing and hunting laws and, in general, protects and manages the state's wildlife resources. The agency ensures that water resource projects and programs—such as reservoir construction and management, water quality standards development, Section 404 permits and pollution-related activities—properly consider and provide for Oklahoma's fish and wildlife.

Federal Water Agencies

The major federal agencies that contribute to the regulation or management of Oklahoma's water resources immediately follow:

The **U.S. Department of Agriculture's Farm Service Agency** administers the Conservation Reserve Program (CRP), Agricultural Conservation Program (ACP) and Swampbuster and Sodbuster provisions of the Food Security Act of 1985, as amended. The Water and Environmental Programs (WEP), administered under USDA's Rural Development Program, provides loans, grants and loan guarantees for drinking water, sanitary sewer, solid waste and storm drainage facilities in rural areas and cities and towns of 10,000 or less. USDA's Natural Resources Conservation Service is responsible for developing and implementing soil and water conservation programs in cooperation with landowners, community planning agencies, and federal, state and local agencies.

The **U.S. Army Corps of Engineers** has major responsibilities in flood protection, navigation and the planning and development of multipurpose water resource projects. The Corps also regulates the disposal of dredge and fill material in navigable waters under the Section 404 (Clean Water Act) permit program.

The **Bureau of Reclamation** assists in the development and conservation of water, power and related land resources throughout the western U.S. Bureau projects are operated to serve municipal and industrial, irrigation, water quality improvement and flood control purposes.

The **Federal Energy Regulatory Commission** provides technical assistance and review of water resource development projects in which hydroelectric power generation is among the project purposes. FERC, an agency of the U.S. Department of Energy, also licenses hydropower projects developed by non-federal entities.

The **U.S. Environmental Protection Agency** administers numerous federal environmental laws regulating water quality, such as the Clean Water Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, Superfund program and National Environmental Policy Act. EPA accomplishes this duty by approving water quality standards used to develop site-specific waste discharge permits, enforcing those permits, and providing technical, emergency, and grant assistance to state and local governments. In addition, EPA is the lead federal agency for administering the Safe Drinking Water and Wastewater Facility Construction Loan Account-State Revolving Funds.

The **U.S. Fish and Wildlife Service** assists states in the planning and development of projects to restore and manage fish and wildlife resources.

The **U.S. Geological Survey** investigates the occurrence, quantity, quality, distribution, use and movement of the nation's surface and groundwater resources. Oklahoma cooperates with the USGS in maintaining stream gaging stations throughout the state.

The **Southwestern Power Administration**, of the Department of Energy, markets hydropower power produced at federal dams in the southwestern U.S.

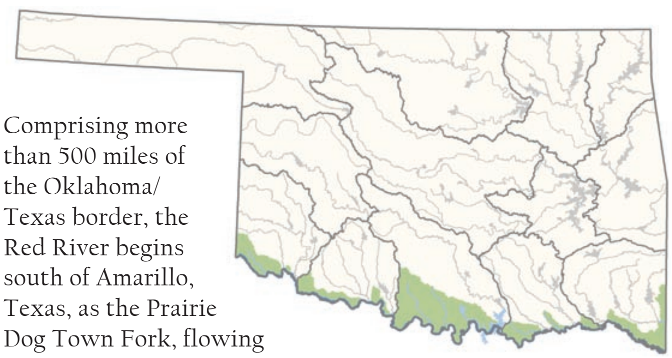
Surface Water Resources

Oklahoma can be divided into two major stream systems, the Red and Arkansas.

Red River and Tributaries

Red River

Length/Distance: 1,360 miles (517 in Oklahoma/Texas)
Drainage Area: 52,182 square miles (22,841 in Oklahoma)
OCWP Regions: Southwest, Beaver-Cache, Lower Washita, Blue Boggy, Southeast



Comprising more than 500 miles of the Oklahoma/Texas border, the Red River begins south of Amarillo, Texas, as the Prairie Dog Town Fork, flowing southeasterly then easterly to begin the southern border of Oklahoma. A few miles downstream it encounters Buck Creek, where it becomes the Red River proper. In Jackson County, the Red River is united with two significant tributaries, Sandy and Gypsum Creeks. Two major contributors to the Red, the Salt Fork and North Fork, join the river south of Altus and west of Frederick in the Southwest Watershed Planning Region.

North Fork of the Red River

Length/Distance: 249 miles (181 in Oklahoma)
Drainage Area: 5,086 square miles (2,801 in Oklahoma)
OCWP Region: Southwest

The North Fork of the Red River originates in Carson County, Texas, and flows eastward where it enters the state just north of I40 near Texola, Oklahoma. Near Sayre, the North Fork turns south, passing through Lugert-Altus Reservoir to its confluence with the mainstem of the Red River west of Davidson. The Elm Fork of the North Fork is the river's major tributary. It begins in the southwestern part of Wheeler County, Texas, and flows east-southeasterly, where it enters Oklahoma near the Harmon/Beckham County line. It continues in the same general direction until it enters the North Fork just below Lugert-Altus Reservoir.

The Salt Fork of the Red River, in the North Fork basin, heads in the High Plains of southern Carson and northern Armstrong Counties in Texas, then flows in a southeasterly direction before entering Oklahoma in rural Harmon County. It continues in the same general direction to its confluence with the mainstem of the Red River near Elmer, Oklahoma. Otter Creek, another tributary of the North Fork, is impounded by Tom Steed Reservoir in Kiowa County.

The North Fork and Salt Fork rivers are typical of the central Great Plains. Some tributaries contribute high sediment loads, while high conductivity is prevalent throughout the mainstems. Chloride concentrations are exceptionally high along the Elm Fork, decreasing down river; lower conductivity water exists throughout the eastern portion of the North Fork watershed. Water clarity is typically average to excellent. Based on algal production, the Elm Fork is typically mesotrophic; the North and Salt Forks range from eutrophic to hypereutrophic. Similarly, Lugert-Altus Reservoir is phosphorus-limited and eutrophic. The watershed contains several sensitive water supplies, including Tom Steed Reservoir, and nutrient limited watersheds, including Rocky (Hobart) Lake.

Cache Creek

Length/Distance: 168 miles (total)
Drainage Area: 1,903 square miles
OCWP Region: Beaver-Cache

Cache Creek, in the Beaver-Cache Region, consists of a relatively short mainstem about nine miles long. The drainage basin is primarily dominated by its two large tributaries, East Cache (86 miles long) and West Cache (73 miles long) Creeks, which traverse Caddo, Comanche, and Cotton Counties. Deep Red Creek, a tributary of West Cache Creek, joins Cache Creek prior to its confluence with the mainstem of the Red River. East Cache Creek is impounded by Lake Ellsworth, one of Lawton's two major water supply sources. Medicine Creek, a contributor to East Cache, is impounded by Lakes Lawtonka and Elmer Thomas near Mount Scott in the Wichita Mountains.

Because of its origin in the Wichita Mountains, conductivity is typically lower along East Cache Creek. Water clarity is average to good and nearly all waters can be classified as eutrophic. Designated as sensitive water supplies, both Lake Ellsworth and Lawtonka are eutrophic with poor to good water quality. Several creeks in the Cache Creek watershed are considered high-quality waters.

Beaver Creek

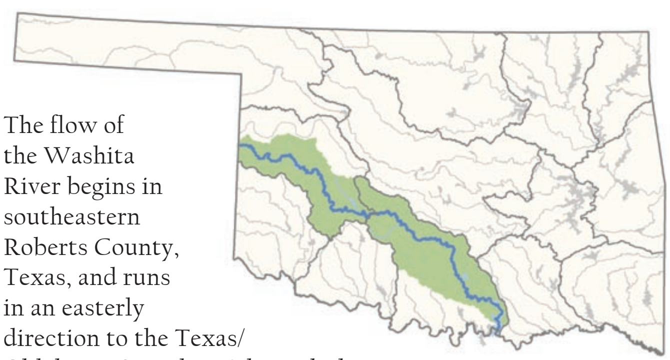
Length/Distance: 84 miles
Drainage Area: 863 square miles
OCWP Region: Beaver-Cache

Beaver Creek originates in northeastern Comanche County and flows predominantly south before it is impounded by Waurika Lake in Jefferson, Stephens, and Cotton Counties before joining the mainstem of the Red River.

Water clarity in Beaver Creek is typically very poor to poor and waters are nutrient-enriched. Along with several other sub-watersheds, Waurika Lake is a sensitive water supply and is eutrophic with average water clarity.

Washita River

Length/Distance: 584 miles (547 in Oklahoma)
Drainage Area: 7,909 square miles (7476 in Oklahoma)
OCWP Regions: West Central, Lower Washita

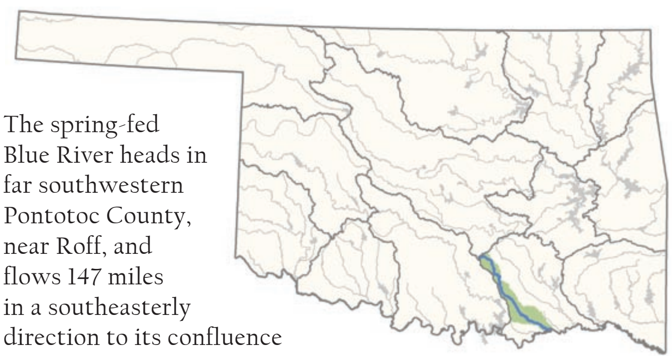


The flow of the Washita River begins in southeastern Roberts County, Texas, and runs in an easterly direction to the Texas/Oklahoma State line. The turbid river then enters Oklahoma in Roger Mills County, flowing southeasterly into Custer County (where it is impounded by Foss Reservoir) then through Washita and Kiowa Counties where it briefly forms the county line and extends east through Caddo County. Cobb Creek, a tributary of the Washita, is impounded by Fort Cobb Reservoir in Caddo County. The Washita River flows out of the West Central into the Lower Washita Region in central Caddo County. It meanders southeastward through Grady County where it is joined from the south by the Little Washita. In Garvin County, it takes a decidedly southward turn through Murray and Carter Counties. After a brief trek to the east, the river enters Johnston County to its termination at Lake Texoma, the state's largest reservoir in terms of storage and the only major project on the mainstem of the Red River in Oklahoma. Arbuckle Reservoir lies on Rock Creek in Murray County. In Garvin County, R.C. Longmire Lake impounds water on Keel Sandy Creek.

Beginning as a sand-dominated channel, the Washita River becomes more heavily influence by silt and clay as it passes through the western and Southern Cross Timbers. Likewise, conductivity decreases and habitat diversity increases down river, leading to more diverse aquatic community. Water clarity ranges from very poor to average with some sand-dominated tributaries having excellent water clarity. Nutrient-enrichment increases as the river changes from eutrophic to hypereutrophic down river. Numerous lakes in the watershed are considered sensitive water supplies, including Fort Cobb and Arbuckle, as well as a number of municipal reservoirs. Additionally, several lakes and watersheds are classified as nutrient limited watersheds. Most lakes are eutrophic to hypereutrophic but clarity ranges from average to excellent.

Blue River

Length/Distance: 132 miles
Drainage Area: 678 square miles
OCWP Region: Blue-Boggy



The spring-fed Blue River heads in far southwestern Pontotoc County, near Roff, and flows 147 miles in a southeasterly direction to its confluence with the Red River in southwest Bryan County. The Blue River basin, contained entirely within the Blue-Boggy Region, is uniquely long and narrow with a maximum width of only about 14 miles. Much of the river's flow is sustained by Byrds Mill spring, the largest spring in Oklahoma.

The Blue River alternates as a gravel/cobble/bedrock/sand system as it passes through the Arbuckle Uplift, but along its middle to lower reaches becomes more influenced by silt. Water clarity is typically good to excellent throughout the watershed. Due to less nutrient-enrichment, much of the watershed is oligotrophic. Much of the upper Blue River is considered high quality water.

Muddy Boggy Creek

Length/Distance: 166 miles
Drainage Area: 2,427 square miles
OCWP Region: Blue-Boggy

Muddy Boggy Creek and its large tributary, Clear Boggy Creek (120 miles long), originate near Ada, in Pontotoc County. The two rivers flow generally parallel to each other in a southeasterly path prior to converging in western Choctaw County. From there, the Muddy Boggy flows to its confluence with the Red River near Hugo. Two of Oklahoma City's water supply lakes in the southeast, Atoka Lake and McGee Creek Reservoir, lie on small tributaries of the Muddy Boggy.

Muddy Boggy Creek and its tributaries are deeply incised slow moving streams. Dissolved solid concentrations are typically low, except in North Boggy Creek. Water clarity is poor to average. Some nutrient enrichment occurs with streams ranging from oligotrophic to eutrophic. Municipal lakes are categorized as sensitive water supplies and are phosphorus limited, ranging from mesotrophic to eutrophic.

Kiamichi River

Length/Distance: 173 miles
Drainage Area: 1,822 square miles
OCWP Region: Southeast

The Kiamichi River begins near Mena, Arkansas along the Oklahoma/Arkansas border, then flows westward near Big Cedar in the Ouachita National Forest in LeFlore County. It meanders into Pushmataha County and is joined by Jackfork Creek, which is impounded by Sardis Reservoir, before turning southwestward then back to the east and south before entering Choctaw County. Just south of the county line, the Kiamichi is impounded by Hugo Lake prior to entering the Red River.

With alternating pools, runs, and riffles, the Kiamichi has exceptionally low dissolved solid content, a slightly acid pH, and normally excellent water clarity. These characteristics, along with exceptional habitat, allow for unique aquatic species to thrive throughout the watershed. The river ranges from oligotrophic to eutrophic with some nutrient enrichment along the lower reaches. The river below Hugo Reservoir has an extremely low gradient with decreased water clarity and biodiversity. Lakes are phosphorus-limited and are generally mesotrophic with very low nutrient values. However, Lake Ozzie Cobb is classified as a nutrient-limited watershed and a number of municipal lakes are classified as sensitive water supplies.

Little River

Length/Distance: 268 miles
Drainage Area: 1955 square miles
OCWP Region: Southeast

The Little River heads in southwestern LeFlore County then crosses westward into Pushmataha County where it assumes a predominantly southern path. As the river enters McCurtain County, it is impounded by Pine Creek Reservoir and joined by the Glover River, its largest tributary, before turning east and leaving Oklahoma at the Arkansas border.

Originating in the Western Ouachita Mountains, the river, much like the Kiamichi, has exceptionally low dissolved solid content, a slightly acid pH, and normally excellent water clarity. These characteristics along with exceptional habitat allow for unique aquatic species to thrive throughout the watershed. With low nutrient concentrations, the watershed is generally mesotrophic. However, Pine Creek Lake has slightly higher nutrient concentrations and is classified as eutrophic. The lower portion of the Little River cuts through lowland terraces. With the exception of a much higher organic content, water chemistry remains relatively constant but the velocity greatly decreases along a much flatter gradient. Much of the watershed is designated as high quality water.

Mountain Fork River

Length/Distance: 93 miles (75 in Oklahoma)
Drainage Area: 843 square miles (594 in Oklahoma)
OCWP Region: Southeast

The headwaters of the scenic Mountain Fork River originate in southwest Arkansas. In Oklahoma, the river resides entirely within McCurtain

County and the Southeast Watershed Planning Region. A section of the river above its impoundment at Broken Bow Lake is noted for its high quality water and has been designated as one of Oklahoma's six "scenic rivers," protected by the State Legislature due to their unique free-flowing beauty and recreational value. Downstream of Broken Bow, the Mountain Fork meanders generally southward to its termination at the Little River.

Originating through the Athens Plateau and Central Mountains Range of the Ouachita Mountains, the upper Mountain Fork has exceptionally low dissolved solid content and typically excellent water clarity. These characteristics, along with exceptional habitat, allow for unique aquatic species to thrive throughout the watershed. With low nutrient concentrations, the watershed is generally oligotrophic. Unlike Pine Creek Reservoir, Broken Bow Reservoir has much lower nutrient concentrations and is classified as mesotrophic. The lower portion of the Mountain Fork River drains the lake and is one of Oklahoma's designated trout fisheries. Much of the watershed is designated as an outstanding resource water and the immediate Broken Bow watershed is also considered a sensitive water supply.

Arkansas River and Tributaries

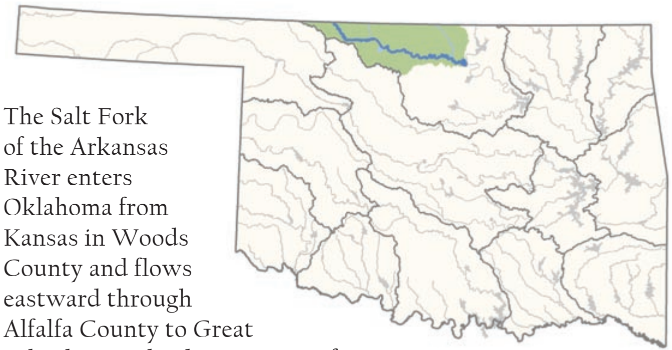
Arkansas River

Length/Distance: 1001 miles (332 in Oklahoma)
Drainage Area: 149,992 square miles (45,091 in Oklahoma)
OCWP Regions: Upper Arkansas, Middle Arkansas, Lower Arkansas

The Arkansas River enters Kay County just south of Arkansas City, Kansas, and is then impounded by Kaw Lake. Flowing southeasterly, it comprises the county line between Osage, Noble, and Pawnee Counties then meanders to the south and east reaching Keystone Lake, a major Corps of Engineers reservoir project impounding both the Arkansas and Cimarron Rivers in northern Oklahoma. From the western extent of the Middle Arkansas Planning Region, and just downstream of Keystone Lake, the Arkansas River continues its southeasterly direction through Tulsa County and the City of Tulsa, then becomes the county line between Wagoner and Muskogee Counties. Following its trek through the Upper and Middle Arkansas Planning Regions, the Arkansas River enters the Lower Arkansas Region in Muskogee County prior to flowing into Webbers Falls Reservoir and Robert S. Kerr Reservoir. It then forms the county line between Sequoyah and LeFlore Counties, leaves Oklahoma, and continues east to its eventual confluence with the Mississippi River. In all, the Arkansas River drains about two-thirds of Oklahoma's land area. Much of the Arkansas River, from Rogers County to the state line, comprises the McClellan-Kerr Navigation System, which links Oklahoma, via New Orleans, with foreign markets throughout the world. Big Lee's Creek and Little Lee's Creek, two far eastern Oklahoma tributaries of the Arkansas in Sequoyah and Adair Counties, are each designated as an Oklahoma "scenic river."

Salt Fork of the Arkansas River

Length/Distance: 216 miles (172 in Oklahoma)
Drainage Area: 6,744 square miles (2,850 in Oklahoma)
OCWP Region: Upper Arkansas



The Salt Fork of the Arkansas River enters Oklahoma from Kansas in Woods County and flows eastward through Alfalfa County to Great Salt Plains Lake downstream of its confluence with Medicine Lodge Creek. The Salt Fork then flows eastward through Grant and Kay Counties where it is joined by the Chikaskia River east of Tonkawa. The Salt Fork terminates at its confluence with the Arkansas River near the Kay/Osage/Noble County line.

The Chikaskia River heads in south central Pratt County, Kansas. Flowing southeasterly, it enters Oklahoma between Grant and Kay Counties then continues southeasterly to its confluence with the Salt Fork in Kay County.

The Salt Fork and Chikaskia Rivers flow in broad, shallow, low-gradient channels. High dissolved solids concentrations occur on the Salt Fork River and many of its tributaries. Water clarity is typically fair to poor. Levels of nutrient enrichment vary with waters ranging from mesotrophic to hypereutrophic. The Great Salt Plains Reservoir is classified as a nutrient-limited watershed.

Cimarron River

Length/Distance: 663 miles (420 miles in Oklahoma)
Drainage Area: 19,045 square miles (8,352 in Oklahoma)
OCWP Regions: Panhandle, Central, Upper Arkansas

The Cimarron River enters the state near the Panhandle town of Kenton in Cimarron County then proceeds easterly and northeasterly where it flows into Colorado in the northeast corner of the county. The river loops north of Texas County before reentering Oklahoma in northeast Beaver County, exits the state again in northwest Harper County, then enters the state for a third time to form a portion of the eastern Harper County line, where it exits the Panhandle Region after marking the boundary between Woodward and Woods Counties, and Major Counties. The Cimarron River enters the Central Planning Region in the southwest corner of Woods County where it forms the Woods/Major County line and continues its decidedly southeasterly direction. Entering Kingfisher County, it flows eastward through Logan County where it enters the Upper Arkansas Planning Region and forms a portion of the boundary between Logan and Payne Counties. The Cimarron then winds slightly to the east-northeast and after entering Creek County continues eastward to its termination in Keystone Lake. Lakes McMurtry and Carl Blackwell, both near Stillwater, are located on Stillwater Creek, just one of dozens of named tributaries that feed the Cimarron on its trek across Oklahoma.

High dissolved solids concentrations occur throughout the Cimarron River watershed, the highest in Woods County. Water clarity is typically average to good, but in tributaries with highly incised banks that are sand/silt/clay-dominated, water clarity becomes poor. With nutrient enrichment throughout, waters range from eutrophic to hypereutrophic. Keystone Lake exhibits average water clarity and is eutrophic. Several municipal lakes are classified as sensitive water supplies. The far upper reaches of the Cimarron are designated as high quality water.

Beaver/North Canadian River

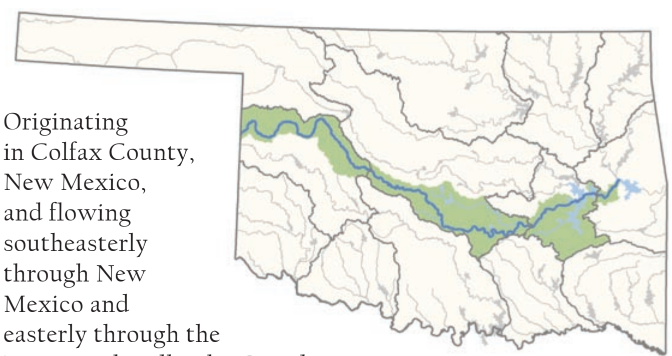
Length/Distance: 782 miles (765 in Oklahoma)
Drainage Area: 17,843 square miles (11,901 in Oklahoma)
OCWP Regions: Panhandle, Central, Eufaula

The North Canadian River, Oklahoma's longest river, has its source in northern Union County, New Mexico. It enters Oklahoma in southwest Cimarron County where it assumes its alias, the Beaver River, then loops south and flows for approximately 12 miles through the State of Texas until it again winds north back into Oklahoma. The Beaver River then takes a sharp northeasterly turn before assuming a primarily eastward path through Beaver County. After entering Harper County, a southeasterly direction is maintained through Woodward County. There it is joined from the southwest by Wolf Creek where it is impounded to form Fort Supply Lake and again becomes the North Canadian River. After flowing through Major and Dewey Counties, the river is impounded in Blaine County by Canton Lake, a water supply for Oklahoma City. From Canton Lake, the North Canadian River enters the Central Region and its watershed narrows considerably as the river flows southeasterly through Canadian, Oklahoma, Lincoln, and Pottawatomie Counties. In this region, the North Canadian is impounded by Lake Overholser, which in tandem with Lake Hefner, an off-channel reservoir in the Cimarron River basin, comprises Oklahoma City's local water supply system. Due to Hefner's small contributing drainage area, the lake depends almost entirely on water furnished through a five-mile long canal from Overholser. A seven-mile portion of the river flowing through Oklahoma City was renamed the Oklahoma River in 2004. In Pottawatomie County, tributaries of the North Canadian are impounded by Wes Watkins Reservoir, Shawnee Twin Lakes, and Lake Tecumseh. The river then forms a portion of the Pottawatomie, Seminole, and Okfuskee County lines and winds into Hughes County, where it enters the Eufaula Planning Region. The North Canadian River concludes its meandering trek from the west in an arm of Lake Eufaula.

Long reaches of the Beaver/North Canadian River experience highly intermittent flows and the channel is often populated with invasive salt cedar. Sand dominates the channel through Canton Lake, but as the river nears Canadian County, it becomes more clay/sand/silt dominated and heavily incised. Below Oklahoma County, the floodplain broadens. High dissolved solids concentrations occur along the Beaver River but gradually decrease to the east. Conversely, water clarity is typically good through the upper reaches but becomes poor to average down river. With nutrient enrichment throughout, waters range from eutrophic to hypereutrophic. Several municipal lakes are classified as sensitive water supplies. Overholser, Fort Supply, and Carl Etling Lakes are designated as nutrient limited watersheds. The far upper reaches of the Beaver are designated as high quality water, although the area is typically dry throughout the year.

Canadian River

Length/Distance: 1,190 miles (460 in Oklahoma)
Drainage Area: 29,640 square miles (6,786 in Oklahoma)
OCWP Regions: West Central, Central, Eufaula, Lower Arkansas



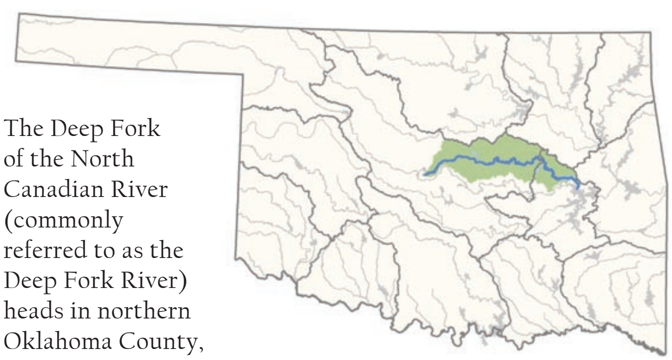
Originating in Colfax County, New Mexico, and flowing southeasterly through New Mexico and easterly through the Texas Panhandle, the Canadian River enters Oklahoma as the gently meandering boundary between Ellis and Roger Mills Counties. It continues this pattern as it flows generally eastward through Dewey County, then takes a decidedly southeastern turn before it leaves the West Central Planning Region near the Canadian County line and enters the Central Region prior to forming the line between Canadian, Grady, Cleveland, McClain, Pottawatomie, Pontotoc, Seminole, Hughes, Pittsburg, and McIntosh Counties. The river leaves the region in Hughes County and enters the Eufaula Region, assuming the western arm of Lake Eufaula. The Canadian River then enters the Lower Arkansas Region forming a portion of the Haskell and Muskogee County lines before it terminates at Robert S. Kerr Reservoir.

The Little River, a major tributary of the Canadian River, heads in northern Cleveland County where it is impounded by Lake Thunderbird and Lake Stanley Draper (on its East Elm Creek tributary). The river then continues east and southeast more or less parallel to its parent river as it bisects Pottawatomie and Seminole Counties, then to its confluence with the Canadian in Hughes County near Holdenville. The Little River is sometimes confused with the river of the same name in the Red River Basin.

Similar to the Cimarron, the Canadian River flows through numerous ecoregions yet maintains certain basic characteristics throughout. Moderately high dissolved solids concentrations occur throughout. Water clarity ranges from poor to average with near excellent water quality below Lake Eufaula. In tributaries with highly incised banks that are sand/silt/clay-dominated, water clarity becomes poor, which is exemplified by the Little River. With nutrient enrichment to Lake Eufaula, waters range from eutrophic to hypereutrophic, but below Eufaula become mesotrophic. The river is impounded by Eufaula Reservoir, which has poor to excellent water clarity and is eutrophic. Several municipal lakes are classified as sensitive water supplies. Lake Thunderbird is designated as a nutrient-limited watershed.

Deep Fork of the North Canadian River

Length/Distance: 203 miles
Drainage Area: 2,538 square miles
OCWP Region: Central, Eufaula

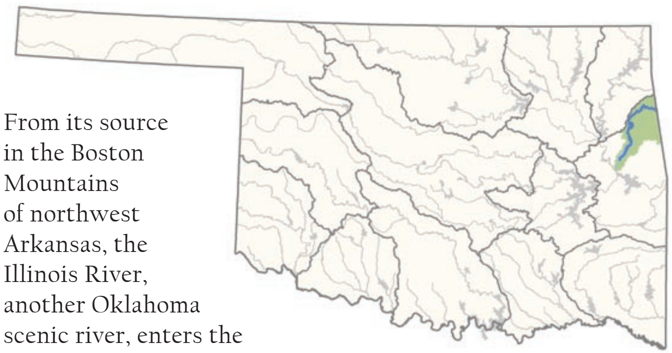


The Deep Fork of the North Canadian River (commonly referred to as the Deep Fork River) heads in northern Oklahoma County, impounding Arcadia Lake, a water supply for the City of Edmond, then flows easterly through Lincoln, Creek, Okfuskee, and Okmulgee Counties prior to leaving the Central Watershed Planning Region. The Deep Fork River enters the Eufaula Region in Okmulgee County and in McIntosh County forms the northern arm of Eufaula Lake to its confluence with the North Canadian River.

The Deep Fork River cuts through a highly incised channel. Throughout, the river is silt/clay/sand dominated, and has low velocity, resulting in very deep pools and often shallow glides. Water clarity is typically poor to fair throughout. With less nutrient enrichment and high turbidity, waters are typically in the high oligotrophic to low eutrophic range.

Illinois River

Length/Distance: 156 miles (104 in Oklahoma)
Drainage Area: 1,645 square miles (897 in Oklahoma)
OCWP Region: Lower Arkansas



From its source in the Boston Mountains of northwest Arkansas, the Illinois River, another Oklahoma scenic river, enters the state in Adair County near the town of Watts. The Illinois then travels southwesterly through Cherokee and Sequoyah Counties where it forms Tenkiller Ferry Lake prior to its confluence with the Arkansas River near the Muskogee/Sequoyah County line. Two important tributaries of the Illinois River, Flint Creek (far upstream in Delaware County) and Barren Fork Creek (which joins the river just upstream of Tenkiller) Creeks, have also been designated as scenic rivers.

The Illinois River and main tributaries meander in broad, moderate gradient valleys and over gravel/cobble/bedrock bottoms. Poultry feeding operation and intense sub-urbanization have become prevalent, impacting water quality. Increasing bank erosion has increased gravel loads to streams and created braided systems with unstable pool habitats and extensive sub-surface flow. Despite extensive riparian disturbance, habitat degradation, and increasing nutrient loads, ecological diversity remains high with several species of fish distinctive to the Ozarks in Oklahoma, including the shadow bass and northern hogsucker. Clarity is typically excellent throughout the watershed. Even with nutrient enrichment, lakes and rivers are typically mesotrophic and may be oligotrophic. Tenkiller Reservoir is a nutrient-limited watershed and several municipal watersheds are designated as sensitive water supplies. A number of streams are also designated as high quality waters.

Poteau River

Length/Distance: 102 miles (95 in Oklahoma)
Drainage Area: 1,895 square miles (1,346 in Oklahoma)
OCWP Region: Lower Arkansas

The Poteau River heads in Scott County, Arkansas, and enters Oklahoma in LeFlore County where it begins a westerly trek to Wister Lake at its confluence with

Fourche Maline Creek. The river then takes a sharp easterly turn and flows north and northeast, uncharacteristic of most Oklahoma rivers. The Poteau terminates at its confluence with the Arkansas River at the Oklahoma/Arkansas border near Fort Smith.

Lying in the eastern portion of the Arkansas Valley, the Poteau River is formed in a broad floodplain with a moderate to low gradient channel divided by Lake Wister. The upper portion of the river has a characteristic gravel/cobble bottom with interspersed riffles and pools. Clarity is near excellent and with low nutrient enrichment, the river is nearly mesotrophic. Below Lake Wister, the river maintains some of its basic characteristics until it nears the town of Poteau. Below this area, influenced by intervening tributaries as well as the Arkansas River back water, river velocity lessens considerably. Clarity becomes poor, and with increased nutrient enrichment, the river becomes eutrophic. Lake Wister, with average water clarity, is considered hypereutrophic and is designated as a nutrient-limited watershed. Several sensitive water supplies and high quality waters exist throughout the watershed. Fourche-Maline Creek exhibits extremely high biodiversity.

Verdigris River

Length/Distance: 327 miles (145 in Oklahoma)
Drainage Area: 8,226 square miles (3,851 in Oklahoma)
OCWP Region: Middle Arkansas

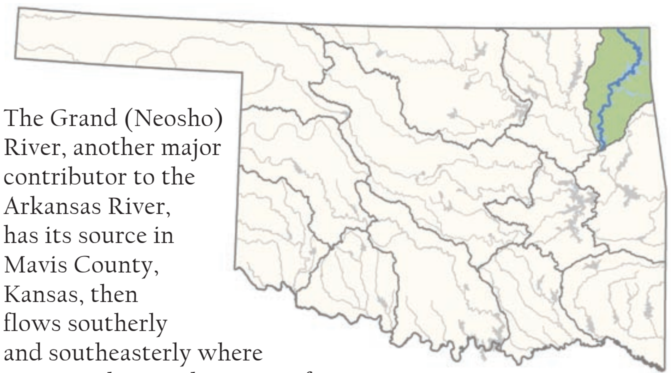
From its source in Greenwood County, Kansas, the Verdigris River flows southerly as it enters Oklahoma in northern Nowata County. As a principal artery of the Arkansas River, it flows in a southerly direction through Oologah Lake into Rogers County where it is joined by the Caney River and Bird Creek just downstream. The Verdigris then enters Wagoner County and joins the Arkansas River as it enters Muskogee County at the far extent of the Middle Arkansas Region.

The Caney River originates in southwestern Elk County, Kansas, then flows southerly and southeasterly where it enters Oklahoma and Hulah Lake in northeast Osage County. It continues east into Washington County where it meets the confluence of the Little Caney River. The Caney briefly flows through Tulsa County before entering Rogers County and its confluence with the Verdigris River near Claremore. Bird Creek, located primarily in Osage and Tulsa Counties, enters the Verdigris River in southern Rogers County. Skiatook Lake is impounded on Hominy Creek, which intersects Bird Creek north of Tulsa.

The Verdigris River and main tributaries meander in broad, low gradient valleys, with highly incised banks. They are typically choked by silt and mud. Clarity may be good in certain upper reaches of Bird Creek, but elsewhere is fair to poor. With nutrient enrichment throughout, waters range from eutrophic to hypereutrophic. Lakes in the watershed, including Oologah, have poor to average water clarity and are typically eutrophic to hypereutrophic. Claremore and Hulah Lakes are nutrient-limited watersheds; several municipal watersheds are designated as sensitive water supplies.

Grand (Neosho) River

Length/Distance: 407 miles (164 in Oklahoma)
Drainage Area: 12,562 square miles (2,962 in Oklahoma)
OCWP Region: Grand



The Grand (Neosho) River, another major contributor to the Arkansas River, has its source in Mavis County, Kansas, then flows southerly and southeasterly where it enters the Ozark Region of northeast Oklahoma forming a portion of the Craig/Ottawa County line. Just upstream of Grand Lake the Grand River is joined by Spring River from the northeast. The river then flows to the southwest, impounded by Lake Hudson and Fort Gibson Lake as it snakes to the south through lush valleys in Mayes, Wagoner, and Cherokee Counties before joining the Arkansas River in Muskogee County. Spavinaw and Eucha Lakes, on Spavinaw Creek, a major tributary of the Grand River that flows westward through Delaware and Mayes Counties, are two of Tulsa's primary water supply reservoirs.

The Neosho River and main tributaries meander in broad low gradient valleys with highly incised banks. Depending on the reach, they may have gravel/cobble bottoms, but are typically choked by silt and mud. To the east, along the upper reaches of the Ozark Highlands, tributaries have a moderate gradient and less incision. They are typically gravel/cobble bottoms with much less silt. Clarity may be average to excellent throughout the watershed. With nutrient enrichment throughout from recent urbanization and animal feeding operations, both lakes and rivers range from mesotrophic to hypereutrophic, depending on placement in the watershed. Eucha, Spavinaw, and Fort Gibson Lakes are nutrient limited watersheds, and several municipal watersheds are designated as sensitive water supplies. Within the Ozark Highlands, several streams are also designated as high quality waters.

Major Surface Water Resources

Major Municipal and Private Reservoirs (1 of 2)

Reservoir Name	Region	Owner/Operator	Year Built	Purpose[1]	Normal Pool Storage	Water Supply		Irrigation		Water Quality	
						Storage	Yield	Storage	Yield	Storage	Yield
					AF	AF	AFY	AF	AFY	AF	AFY
Altus City	Southwest	City of Altus	1940	WS, R	2,500	---	---	---	---	---	---
Atoka	Blue-Boggy	City of Oklahoma City	1964	WS, R	105,195	123,500	92,067	0	0	0	0
Bell Cow	Central	City of Chandler	1990	FC, WS R	15,613	---	4,558	---	---	---	---
Bixhoma	Middle Ark	City of Bixby	1965	WS, R	3,130	---	---	---	---	---	---
Bluestem	Middle Ark	City of Pawhuska	1958	WS, R	17,000	---	---	---	---	---	---
Boomer	Upper Ark	City of Stillwater	1932	CW, R	3,200	---	---	---	---	---	---
Carl Albert	Southeast	City of Talihina	1964	WS. FC, R	2,739	---	---	0	0	0	0
Chandler	Central	City of Chandler	1954	WS, R	2,778	2,778	---	0	0	0	0
Chickasha	Lower Wash	City of Chickasha	1958	WS, R	41,080	---	---	0	0	0	0
Claremore	Middle Ark	City of Claremore	1930	WS, R	7,900	---	---	---	---	---	---
Clear Creek	Lower Wash	City of Duncan	1948	WS, R	7,710	---	---	0	0	0	0
Cleveland City	Upper Ark	City of Cleveland	1936	WS, R	2,200	---	---	---	---	---	---
Clinton	West Central	City of Clinton	1931	WS, R	3,980	---	---	---	---	---	---
Coalgate	Blue-Boggy	City of Coalgate	1965	WS, FC, R	3,466	---	---	0	0	0	0
Cushing	Upper Ark	City of Cushing	1950	WS, R	3,304	---	---	---	---	---	---
Dave Boyer	Beaver-Cache	City of Walters	1936	WS, R	936	---	---	---	---	---	---
Dead Warrior	West Central	City of Cheyenne	1959	FC, R	977	---	---	0	0	0	0
Dripping Springs	Eufaula	City of Okmulgee	1976	WS, FC, R	16,200	---	7,214	0	0	0	0
Duncan	Lower Wash	City of Duncan	1937	WS, R	7,200	---	---	0	0	0	0
El Reno	Central	City of El Reno	1966	FC, R	709	---	---	0	0	0	0
Elk City	Southwest	City of Elk City	1970	FC, R	2,583	---	---	---	---	---	---
Ellsworth	Beaver-Cache	City of Lawton	1962	WS, R	81,224	68,700	23,500	0	0	0	0
Eucha	Grand	City of Tulsa	1952	WS, R	79,570	110,200	84,000	0	0	0	0
Fairfax City	Upper Ark	City of Fairfax	1936	WS, R	1,795	---	---	---	---	---	---
Frederick	Beaver-Cache	City of Frederick	1974	WS, FC, R	9,663	---	---	0	0	0	0
Fuqua	Lower Wash	City of Duncan	1962	WS. FC, R	21,100	21,100	3,427	0	0	0	0
Guthrie	Central	City of Guthrie	1919	WS, R	3,875	---	---	---	---	---	---
Healdton	Lower Wash	City of Healdton	1979	WS, FC, R	3,766	---	413	0	0	0	0
Hefner	Central	City of Oklahoma City	1947	WS, R	68,868	75,000	---	0	0	0	0
Henryetta	Eufaula	City of Henryetta	1928	WS, R	6,660	---	---	---	---	---	---
Holdenville	Central	City of Holdenville	1931	WS, R	11,000	11,000	---	0	0	0	0
Hominy Municipal	Middle Ark	City of Hominy	1940	WS, R	5,000	---	---	---	---	---	---
Hudson	Middle Ark	City of Bartlesville	1949	WS, R	4,000	---	---	---	---	---	---
Humphreys	Lower Wash	City of Duncan	1958	WS, FC, R	14,041	---	3,226	0	0	0	0
John Wells	Lower Ark	City of Stigler	1936	WS, R	1,352	---	---	---	---	---	---
Konawa	Central	OG&E	1968	CW	23,000	---	---	0	0	0	0
Langston	Upper Ark	City of Langston	1966	WS, FC, R	5,792	---	---	0	0	0	0
Lawtonka	Beaver-Cache	City of Lawton	1905	WS, R	55,171	64,000	23,500	0	0	0	0
Liberty	Central	City of Guthrie	1948	WS, R	2,740	---	---	0	0	0	0
Lloyd Church	Lower Ark	City of Wilburton	1964	WS, FC, R	3,025	---	1,523	0	0	0	0
Lone Chimney	Upper Ark	Tri-County Dev Auth	1984	WS, FC, R	6,200	---	2,509	0	0	0	0
McAlester	Eufaula	City of McAlester	1930	WS, R	13,398	16,900	9,200	0	0	0	0
McMurtry	Upper Ark	City of Stillwater	1971	WS, FC, R	19,733	13,500	3,002	0	0	0	0
Meeker	Central	City of Meeker	1970	WS, FC, R	1,976	---	202	0	0	0	0
New Spiro	Lower Ark	City of Spiro	1960	WS, R	2,160	---	---	---	---	---	---
Okemah	Central	City of Okemah	N/A	WS, R	10,392	10,392	2,200	---	---	---	---
Okmulgee	Eufaula	City of Okmulgee	1928	WS, R	14,170	---	---	---	---	---	---

Major Municipal and Private Reservoirs (2 of 2)

Reservoir Name	Region	Owner/Operator	Year Built	Purpose[1]	Normal Pool Storage	Water Supply		Irrigation		Water Quality	
						Storage	Yield	Storage	Yield	Storage	Yield
					AF	AF	AFY	AF	AFY	AF	AFY
Overholser	Central	City of Oklahoma City	1919	WS, R	13,913	17,000	5,000	0	0	0	0
Pauls Valley	Lower Wash	City of Pauls Valley	1954	WS, R	8,730	---	---	---	---	---	---
Pawhuska	Middle Ark	City of Pawhuska	1936	WS, R	3,600	---	---	---	---	---	---
Pawnee	Upper Ark	City of Pawnee	1932	WS, R	3,855	---	---	---	---	---	---
Perry	Upper Ark	City of Perry	1937	WS, FC, R	6,358	---	---	0	0	0	0
Ponca	Upper Ark	City of Ponca City	1935	WS, R	14,440	15,300	2,529	0	0	0	0
Prague City	Central	City of Prague	1984	WS, FC, R	2,415	---	549	0	0	0	0
Purcell	Central	City of Purcell	1930	WS, R	2,600	---	---	---	---	---	---
RC Longmire	Lower Wash	City of Pauls Valley	1989	WS, FC, R	N/A	13,162	3,360	0	0	0	0
Rocky	Southwest	City of Hobart	1933	WS, R	4,210	---	---	---	---	---	---
Sahoma	Middle Ark	City of Sapulpa	1947	WS, R	4,850	---	---	---	---	---	---
Shawnee Twin	Central	City of Shawnee	1935/1960	WS, R	34,000	34,000	4,400	---	---	---	---
Shell	Middle Ark	City of Sand Springs	1922	WS, R	9,500	---	---	---	---	---	---
Sooner	Upper Ark	OG&E	1972	CW	149,000	149,000	3,600	0	0	0	0
Spavinaw	Grand	City of Tulsa	1924	WS, R, FW	30,590	---	---	---	---	---	---
Sportsman	Eufaula	City of Seminole	1958	FC, R	5,349	---	---	---	---	---	---
Stanley Draper	Central	City of Oklahoma City	1962	WS, R	87,296	100,000	---	0	0	0	0
Stilwell City	Lower Ark	City of Stilwell	1965	WS, FC, R	3,110	---	---	---	---	---	---
Stroud	Central	City of Stroud	1968	WS, FC, R	8,800	---	1,299	---	---	---	---
Talawanda #2	Eufaula	City of McAlester	1924	WS, R	2,750	---	---	---	---	---	---
Taylor	Lower Wash	City of Marlow	1960	WS, FC, R	1,877	---	---	---	---	0	0
Tecumseh	Central	City of Tecumseh	1934	WS, R	1,118	---	---	0	0	0	0
Waxhoma	Middle Ark	City of Barnsdall	1955	WS, R	2,000	---	---	---	---	---	---
Weleetka	Eufaula	City of Weleetka	1923	WS, R	385	---	---	---	---	---	---
Wes Watkins	Central	Pott. County Dev. Auth.	1997	FC, WS, R	14,065	---	---	0	0	0	0
Wetumka	Central	City of Wetumka	1939	WS, R	1,839	---	---	---	---	---	---
Wewoka	Eufaula	City of Wewoka	1925	WS, R	3,301	---	---	---	---	---	---
Wiley Post Memorial	Lower Wash	City of Maysville	1971	WS, FC, R	2,082	0	538	0	0	0	0
Yahola	Middle Ark	City of Tulsa	1948	WS, R	6,445	---	---	0	---	---	---

1 *WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water*

No known information is annotated as "---"

Major State & Federal Reservoirs

Reservoir Name	Region	Owner/ Operator[1]	Year Built	Purpose[2]	Normal Pool Storage	Water Supply		Irrigation		Water Quality	
						Storage	Yield	Storage	Yield	Storage	Yield
					AF	AF	AFY	AF	AFY	AF	AFY
Arbuckle	Lower Wash	BuRec	1967	WS, FC, FW, R	72,400	62,600	24,000	0	0	0	0
Arcadia	Central	USACE	1986	FC, WS, R	29,544	23,090	12,320	---	---	---	---
Birch	Middle Ark	USACE	1977	FC, WS, WQ, R, FW	19,225	7,600	3,360	---	---	7,600	3,360
Broken Bow	Southeast	USACE	1970	FC, HP, WS, R, FW	918,070	152,500	196,000	0	0	0	0
Brushy	Lower Ark	State of OK	1964	WS, FC, R	3,258	---	---	0	0	0	0
Canton	Panhandle	USACE	1948	FC, WS, IR	111,310	38,000	16,240	69,000	2,240	0	0
Carl Blackwell	Upper Ark	OSU	1937	WS. R	61,500	55,000	7,000	0	0	0	0
Copan	Middle Ark	USACE	1983	FC, WS, WQ, R, FW	43,400	7,500	3,360	---	---	26,100	17,920
Crowder	West Central	State of OK	1959	FC, R	2,094	---	---	---	---	---	---
Eufaula	Eufaula	USACE	1964	FC, WS, HP, N, R	2,314,600	56,000	56,000	0	0	0	0
Fort Cobb	West Central	BuRec	1959	FC, WS, FW, R	80,010	78,350	18,000	0	0	0	0
Fort Gibson	Grand	USACE	1953	FC, HP	365,200	0	0	0	0	0	0
Fort Supply	Panhandle	USACE	1942	FC, C	13,900	400	224	0	0	0	0
Foss	West Central	BuRec	1961	IR, FC, WS, FW, R	256,220	165,480	18,000	0	0	0	0
Grand	Grand	GRDA	1940	FC, HP	1,515,414	0	0	0	0	0	0
Great Salt Plains	Upper Ark	USACE	1941	FC, C, FW	31,420	0	0	0	0	0	0
Heyburn	Middle Ark	USACE	1950	FC, WS, R, FW	5,307	2,000	1,904	---	---	0	0
Hudson (Markham Ferry)	Grand	GRDA	1964	FC, HP	200,185	0	0	0	0	0	0
Hugo	Southeast	USACE	1974	FC, WS, WQ, R, FW	158,617	47,600	64,960	0	0	73,900	100,800
Hulah	Middle Ark	USACE	1951	FC, WS, LF, R, FW	31,160	19,800	11,088	---	---	7,100	5,040
Kaw	Upper Ark	USACE	1976	FC, WS, HP, WQ, R, FW	428,600	171,200	187,040	0	0	31,800	43,680
Keystone	Upper Ark	USACE	1964	FC, WS, HP, N, FW	557,600	20,000	22,400	0	0	0	0
Lugert-Altus	Southwest	BuRec	1947	FC, WS, IR	132,830	132,830	47,100	0	0	0	0
McGee Creek	Blue-Boggy	BuRec	1987	WS, WQ, FC, R, FW	113,930	109,800	71,800	0	0	0	0
Murray	Lower Wash	State of OK	1938	R	153,250	111,921	1,008	0	0	0	0
Oologah	Middle Ark	USACE	1963	FC, WS, N, R, FW	552,210	342,600	172,480	168,000	91,224	0	0
Optima	Panhandle	USACE	1978	FC, WS, R, FW	129,000	117,650	---	0	0	0	0
Pine Creek	Southeast	USACE	1969	FC, WS, WQ, FW, R	53,750	49,400	94,080	0	0	21,100	40,330
Robert S Kerr	Lower Ark	USACE	1970	N, HP, R	525,700	0	0	0	0	0	0
Sardis	Southeast	USACE	1982	FC, WS, R, FW	274,330	274,209	156,800	0	0	0	0
Skiatook	Middle Ark	USACE	1984	FC, WS, WQ, R, FW	322,700	62,900	15,680	---	---	233,000	69,440
Tenkiller Ferry	Lower Ark	USACE	1953	FC, HP	654,100	25,400	29,792	0	0	0	0
Texoma	Lower Wash	USACE	1944	FC, WS, HP, LF, R	2,643,000	150,000	168,000	0	0	0	0
Thunderbird	Central	BuRec/COMCD	1965	FC, WS, R, FW	105,644	105,900	21,700	0	0	0	0
Tom Steed	Southwest	BuRec	1975	WS, FC, R, FW	88,970	88,160	16,000	0	0	0	0
W.R. Holway	Grand	GRDA	1968	WS, HP, R	50,372	---	---	---	---	---	---
Waurika	Beaver-Cache	USACE	1977	FC, IR, WS, WQ, R, FW	203,100	151,400	40,549	16,200	5,041	0	0
Wayne Wallace	Lower Ark	State of OK	1969	R, FC	1,746	---	---	---	---	---	---
Webbers Falls	Lower Ark	USACE	1970	N, HP	170,100	0	0	0	0	0	0
Wister	Lower Ark	USACE	1949	FC, WS, LF, C	47,414	14,000	31,364	0	0	0	0

1 BuRec=Bureau of Reclamation, USACE=U.S. Army Corps of Engineers, OSU=Oklahoma State University, GRDA=Grand River Dam Authority, COMCD=Central Oklahoma Master Conservancy District

2 *WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water*

No known information is annotated as "---"

Groundwater Resources

Aquifers in Oklahoma range in geologic age from Cambrian (570 million years) to Quaternary (1.6 million years to present). Older formations, generally referred to as bedrock aquifers, are typically more consolidated (solid), consisting of sandstone, shale, limestone, dolomite, and gypsum. Alluvial aquifers are younger deposits of unconsolidated sand, silt, and clay.

The OWRB defines major bedrock aquifers as those yielding an average of at least 50 gallons per minute (gpm) of water to wells, and major alluvial aquifers as those yielding, on average, at least 150 gpm. Several minor aquifers in Oklahoma also serve as important sources of water for domestic, stock, and other uses. The OWRB has identified 10 major bedrock and 11 major alluvial aquifers. The bedrock aquifers include the Antlers, Arbuckle-Simpson, Arbuckle-Timbered Hills, Blaine, Elk City, Garber-Wellington, Ogallala, Roubidoux, Rush Springs, and Vamoosa-Ada. The major alluvial aquifers are the Arkansas River, Canadian River, Cimarron River, North Canadian River, North Fork of the Red River, Red River, Salt Fork of the Arkansas River, Washita River, Enid Isolated Terrace, Gerty Sand, and Tillman Terrace.

Groundwater is water that has percolated downward from the surface, filling voids or open spaces in rock formations. The underground zone of water saturation begins at the point where subsurface voids are full or saturated. An aquifer is a rock formation that is capable of holding and yielding significant amounts of groundwater. The amount of water stored in an aquifer depends on the saturated thickness (the vertical thickness of an aquifer that is filled with water), area of the aquifer, and specific yield (the ratio of the volume of water a given mass of saturated material will yield by gravity to the volume of that mass).

The natural quality of groundwater reflects the chemical composition of the rocks with which it comes in contact. As water seeps through soil and rock, it takes varying types and concentrations of minerals into solution, depending upon the geologic constituents of individual formations, solubility of minerals in those formations, and duration of contact.

The total dissolved solids content in a water sample is often used as a general indicator of water quality. Although the OWRB considers water with a dissolved solid concentration of less than 5,000 mg/L (milligrams per liter) to be fresh, water is usually considered undesirable for drinking if the quantity of dissolved minerals exceeds 500 mg/L. Hardness is an indication of the concentration of alkaline salts in water, primarily calcium and magnesium; water described as hard is high in calcium and magnesium. Hard water is not considered a health risk, but rather a nuisance because of the mineral buildup it causes on fixtures and poor soap and/or detergent performance.

In general, Oklahoma's major aquifers contain water of acceptable quality for irrigation of at least some crops. Except for the Blaine aquifer, in southwest Oklahoma, where high sulfate concentrations preclude its use for public water supply, the state's major aquifers provide water supplies that generally meet or exceed federal and state standards for drinking water. However, not all areas or depths within these aquifers produce water suitable for public supply.

In many areas of the state, high concentrations of dissolved solids limit groundwater use. High chloride and sulfate concentrations are a problem in western Oklahoma, where thick deposits of salt and gypsum occur in many Permian-age formations. Saline waters from adjoining Permian formations can migrate into portions of alluvial aquifers. In most bedrock aquifers, salinity also increases with depth due to brines that are present in underlying geologic units. Other naturally occurring constituents, such as arsenic, selenium, and fluoride, limit use of groundwater in some aquifers as a source of public drinking water.

Human activities can impact groundwater quality by contributing nitrate, chloride, and other substances to underground supplies. Nitrate contamination from non-point sources, such as animal wastes, sewage, and fertilizers, is widespread throughout the state. Where nitrate concentrations exceed the U.S. EPA drinking water standard of 10 mg/L, water is impaired for public drinking supplies. Other instances of human-induced groundwater pollution are generally isolated. Examples of anthropogenic pollution include chloride from discontinued oil field activities and injection wells, metals from past mining operations, pesticides, and hydrocarbons.

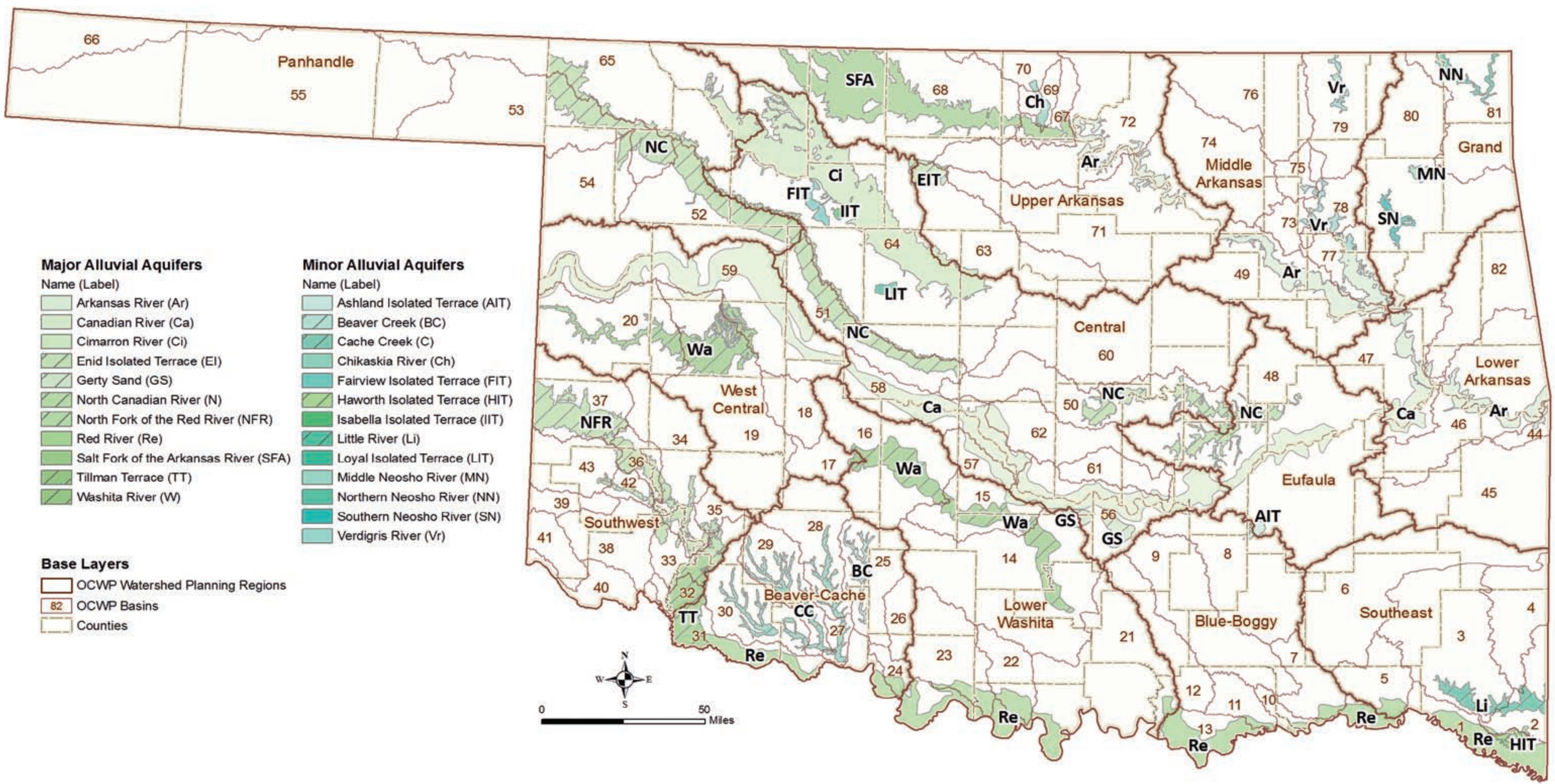
Alluvial Aquifers

Alluvial aquifers occur along the larger streams in Oklahoma and are major sources of water for irrigation, municipal, industrial, household, and stock purposes. These aquifers are comprised of river alluvium, terrace deposits, and dune sand of Quaternary age. River alluvium is the material constantly being eroded, transported, and deposited by a river. Terrace deposits are older floodplain or alluvial deposits that have been left behind after a stream shifts position. These sediments are unconsolidated or poorly consolidated and consist of sand, gravel, silt, and clay. Hydrologically, alluvium and terrace deposits constitute a single water-bearing unit.

Alluvial and terrace deposits along the major rivers in Oklahoma (the Arkansas, Salt Fork of the Arkansas, Red, North Canadian, Canadian, Washita, North Fork of the Red River, and Cimarron) extend from one to 15 miles from the river banks. The thickness of these deposits ranges from a few feet to as much as 200 feet. Yields of wells generally range from 10 to 500 gpm, but can locally be greater than 1,000 gpm. The Gerty Sand (covering an aerial extent of 110 square miles) and Enid Isolated Terrace (81 square miles) aquifers, among others, represent small alluvial deposits that became separated from larger deposits by erosion.

Water from Oklahoma's alluvial aquifers, though typically very hard, is generally of good quality and is acceptable for most purposes. In some western areas, however, quality is poor due to high concentrations of chloride and sulfate. These minerals occur naturally when saline water from layers of salt and gypsum in adjacent Permian red beds infiltrate alluvial aquifers. These aquifers are especially vulnerable to contamination from surface activities. As a result, high nitrate concentrations in many alluvial aquifers decrease their suitability for public supply.

Major and Minor Alluvial Aquifers



Major and Minor Alluvial Aquifers

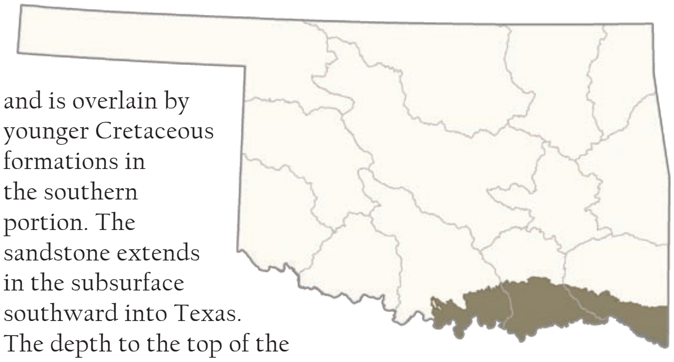
Aquifer		Recharge Rate	Aquifer Storage	Equal Proportionate Share
Name	Class[1]	Inch/Yr	AF	AFY/Acre
Arkansas River	Major	5.0	946,000	temporary 2.0
Canadian River	Major	2.0	5,010,000	temporary 2.0
Cimarron River	Major	2.3	3,859,000	temporary 2.0
Enid Isolated Terrace	Major	2.3	246,000	0.5
Gerty Sand	Major	1.0	224,000	0.7
North Canadian River	Major	1.0-5.0	8,216,000	0.8-1.3
North Fork of the Red River	Major	2.3	3,763,000	1.0
Red River	Major	2.5	2,589,000	temporary 2.0
Salt Fork of the Arkansas River	Major	2.3	2,184,000	temporary 2.0
Tillman Terrace	Major	2.9	1,282,000	1.0
Washita River	Major	2.65-4.41	4,920,000	1.0-1.5
Ashland Isolated Terrace	Minor	3.9	81,000	temporary 2.0
Beaver Creek	Minor	3.6	151,000	1.0
Cache Creek	Minor	3.6	746,000	1.0
Chikaskia River	Minor	4.5	89,000	temporary 2.0
Fairview Isolated Terrace	Minor	0.8	78,000	temporary 2.0
Haworth Isolated Terrace	Minor	4.8	22,000	1.0
Isabella Isolated Terrace	Minor	0.8	26,000	temporary 2.0
Little River	Minor	4.8	247,000	1.0
Loyal Isolated Terrace	Minor	0.8	63,000	temporary 2.0
Middle Neosho River	Minor	4.2	30,000	temporary 2.0
Northern Neosho River	Minor	4.2	71,000	temporary 2.0
Southern Neosho River	Minor	4.2	51,000	temporary 2.0
Verdigris River Groundwater Basin	Minor	4.2	162,000	temporary 2.0

1 Alluvial aquifers with typical yields greater than 150 gpm are considered major.

Major Bedrock Aquifers

Antlers

The Antlers aquifer underlies a large area of southeastern Oklahoma. It is comprised of the Cretaceous-age Antlers Sandstone, which consists of poorly cemented sandstone with some layers of sandy shale, silt, and clay. The Antlers Sandstone outcrops in the northern one-third of the aquifer and is overlain by younger Cretaceous formations in the southern portion. The sandstone extends in the subsurface southward into Texas. The depth to the top of the Antlers Sandstone from land surface where it extends into the subsurface varies from several feet near its outcrop to a maximum of 1,000 feet at its deepest point in Oklahoma.



The saturated thickness, averaging 360 feet, ranges from less than 5 feet at the northern outcrop limit to about 1,000 feet near the Red River. Large-capacity wells tapping the Antlers aquifer commonly yield 100 to 500 gpm, with reported production as high as 1,700 gpm. Water usage from the aquifer is minimal due to the availability of surface water. In 2000, about 4,900 acre-feet of water was pumped for public supply, irrigation, and industrial uses.

The quality of water in the Antlers is generally good with a total dissolved solids (TDS) concentration of 200 to 1,000 mg/L. Water becomes slightly saline down dip with dissolved solids greater than 1,000 mg/L in the southern portions of the aquifer.

Arbuckle-Simpson

The Arbuckle-Simpson aquifer consists of several formations that make up the Arbuckle and Simpson Groups, which crop out in the Arbuckle Mountains geologic province. The rocks were subjected to intensive folding and faulting associated with major uplift of the area during early to late Pennsylvanian time. The western portion of the aquifer, referred to as the Arbuckle Anticline, is characterized by a series of northwest-trending ridges formed on resistant rocks. The eastern portion of the aquifer, referred to as the Hunton Anticline area, is characterized by a gently rolling topography formed on relatively flat-lying, highly-faulted dolomite.

Rocks of the Arbuckle Group are primarily limestone and dolomite whereas those of the Simpson Group are sandstone, shale, and limestone. About 2/3 of the aquifer consists of soluble carbonate rocks (limestones and dolomites). Infiltrating water slowly dissolves the rock, leading to the formation of solution channels and cavities along bedding planes, fractures, and faults. Water is stored in solution openings in the carbonate rocks and in the porous sandstones of the Simpson Group. Saturated thickness is estimated to be from 2,000 to 3,500 feet.

Wells in the Arbuckle Group commonly yield 25 to 600 gpm of water; deep wells yield more than 1,000 gpm. Wells in the Simpson Group typically yield 100 to 200 gpm. To date, water in the aquifer has been produced in only small amounts for municipal, industrial, commercial, agricultural, livestock, and domestic purposes. In 1989, the EPA designated the eastern portion of the aquifer as a sole source aquifer. The aquifer is the principal source of water for the cities of Ada, Sulphur, Mill Creek, and Roff. Water is of good quality, generally less than 500 mg/L dissolved solids.

Groundwater discharges to numerous springs along the periphery of the outcrop. The largest spring issuing from the aquifer is Byrds Mill Spring, located in the northeastern margin of the Hunton Anticline region near Fittstown. The spring flows an average 18 cubic feet per second (8,080 gpm) and supplies water for the City of Ada. Other well-known springs that discharge from the aquifer include Antelope and Buffalo Springs, located in the Chickasaw National Recreational Area near the town of Sulphur. The many springs emanating from the aquifer provide flow to several headwater streams, including Blue River and Honey, Pennington, Mill, and Travertine Creeks.

Arbuckle-Timbered Hills

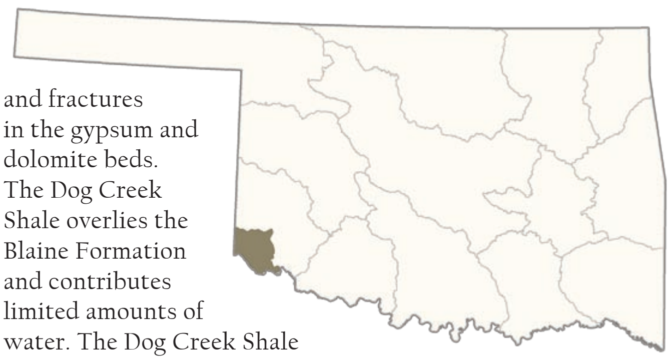
The Arbuckle-Timbered Hills aquifer in southwestern Oklahoma consists of several formations that make up the Arbuckle and Timbered Hills Groups. These formations consist of limestone and dolomite with some interbedded sandstone and shale. The rocks are intensely folded and faulted. Most groundwater movement is made possible by solution of the limestone and dolomite along bedding planes, fractures, and faults. The aquifer occurs in two areas: in the Limestone Hills north of the Wichita Mountains, where rocks of the Arbuckle and Timbered Hills Groups crop out, and in the Cache-Lawton area south of the Wichita Mountains, where the aquifer is overlain by as much as 2,000 feet of younger rocks.

Availability of groundwater in the Limestone Hills is erratic because of faulting and folding. Most wells are at least 500 feet deep and water generally is under artesian conditions. Flowing wells and springs yield as much as 100 gpm. In the Cache-Lawton area, well depths range from 350 feet near the mountains to more than 2,000 feet at Geronimo. Yields up to 600 gpm have been reported. The Arbuckle-Timbered Hills aquifer is largely undeveloped.

Water from the Limestone Hills area is very hard calcium bicarbonate water and sometimes contains hydrogen sulfide gas. Dissolved solids range from 195 to 940 mg/L. Water from the Cache-Lawton area is a soft, sodium chloride type water with dissolved solids ranging from 279 to 6,380 mg/L. Concentrations of fluoride range from 1.6 to 17 mg/L. Because fluoride concentrations generally exceed the drinking water standard, use for public water supply is limited.

Blaine

The Blaine aquifer, in southwestern Oklahoma, consists of the Permian-age Blaine Formation and Dog Creek Shale. The Blaine Formation is usually between 300 and 400 feet thick and consists of a series of interbedded gypsum, shale, and dolomite. Water is obtained from cavities, solution channels



and fractures in the gypsum and dolomite beds. The Dog Creek Shale overlies the Blaine Formation and contributes limited amounts of water. The Dog Creek Shale consists of up to 200 feet of red-brown shale with thin gypsum and dolomite beds in the lower 50 feet of the formation.

Water from the Blaine aquifer is of poor quality with dissolved solids ranging from 1,500 to 5,000 mg/L. The water has high concentrations of calcium and sulfate, reflecting dissolution of the gypsum beds. Locally, in southeastern and northwestern Harmon County, the water has high sodium chloride content. Although the highly mineralized aquifer is unsuitable as a drinking water supply, it is a major source of irrigation water. Irrigation wells are typically 100 to 300 feet deep with yields between 100 and 500 gpm, although they can exceed 2,000 gpm.

Natural recharge to the basin occurs from infiltration of precipitation and from streams that flow across sinkholes and solution openings. Average recharge to the aquifer is estimated at 1.5 inches per year, or 6% of the average annual precipitation of 24 inches. Local farmers channel runoff into artificial recharge wells to supplement the natural recharge.

Elk City

The Elk City aquifer, in western Oklahoma, is comprised of the Permian-age Elk City Sandstone. The sandstone is fine-grained and very friable with a maximum thickness of about

185 feet. Wells commonly yield 25 to 300 gpm of water for irrigation, domestic and industrial purposes.

Garber-Wellington (Central Oklahoma)

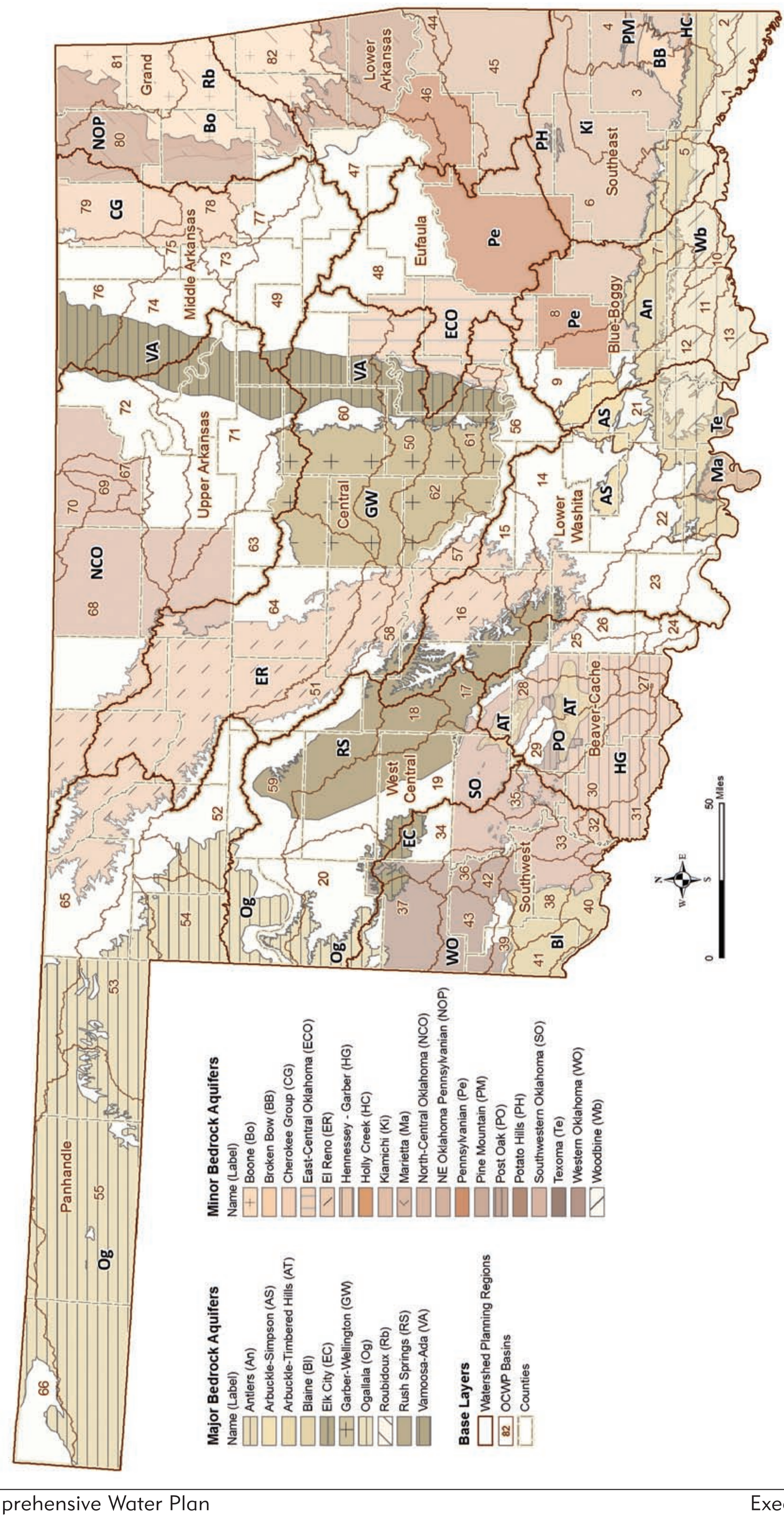
The Garber-Wellington aquifer, also referred to as the Central Oklahoma aquifer, is comprised primarily of the Permian-age Garber Sandstone and Wellington Formation. Also included in the aquifer are the Permian-age Chase, Council Grove, and Admire Groups (formerly classified as the Pennsylvanian-age Oscar Group). The aquifer consists of fine-grained sandstone interbedded with siltstone and shale. The total thickness of

the combined formations is about 1,000 feet. Depth to water varies from less than 100 feet to 350 feet; saturated thickness ranges from 150 to 650 feet. Non-domestic wells completed in the aquifer can yield as much as 600 gpm but generally yield from 200 to 400 gpm.

Water from the aquifer is normally suitable for public water supply but in some areas concentrations of nitrate, arsenic, chromium, uranium, and selenium may exceed drinking water standards. Elevated concentrations of nitrate occur in shallow water which can be a concern for domestic well users. Elevated concentrations of arsenic, chromium, and selenium occur in deep parts of the aquifer, which mostly affects public supply wells. The highest concentrations of arsenic tend to occur in the western portion of the aquifer, where it is overlain by the younger Hennessey Group.

The Garber-Wellington aquifer is an important source of domestic and public water supply. The aquifer is overlain in places by alluvial aquifers along the North Canadian and Canadian Rivers. Water is available from both aquifers. With the exception of Oklahoma City, all the major communities in central Oklahoma rely either solely or partly on groundwater from the Garber-Wellington.

Major and Minor Bedrock Aquifers



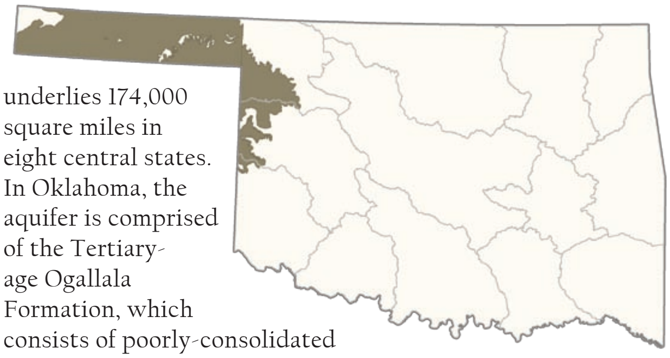
Major and Minor Bedrock Aquifers

Aquifer		Recharge Rate	Aquifer Storage	Equal Proportionate Share
Name	Class[1]	Inch/Yr	AFY	AFY/acre
Antlers	Major	0.3-1.7	53,570,000	2.1
Arbuckle-Simpson	Major	5.6	9,470,000	temporary 2.0
Arbuckle-Timbered Hills	Major	0.3-0.6	962,000	temporary 2.0
Blaine	Major	1.5	1,403,000	temporary 2.0
Elk City	Major	2.8	2,244,000	1.0
Garber-Wellington	Major	1.6	58,583,000	temporary 2.0
Ogallala	Major	0.5-0.9	90,590,000	1.4 to 2.0
Roubidoux	Major	2.5	43,029,000	temporary 2.0
Rush Springs	Major	1.8	79,838,000	temporary 2.0
Vamoosa-Ada	Major	0.7-1.4	14,931,000	2.0
Boone	Minor	10.5	33,751,000	temporary 2.0
Broken Bow	Minor		258,000	temporary 2.0
Cherokee Group	Minor	3.0	1,452,000	temporary 2.0
East-Central Oklahoma	Minor	2.8	13,940,000	temporary 2.0
El Reno	Minor	0.8	18,750,000	temporary 2.0
Hennessey-Garber	Minor	2.7	5,999,000	1.6
Holly Creek	Minor		70,000	temporary 2.0
Kiamichi	Minor	1.1	2,335,000	temporary 2.0
North-Central Oklahoma	Minor	1.0	14,250,000	temporary 2.0
Northeastern Oklahoma Pennsylvanian	Minor	2.1	3,712,000	temporary 2.0
Pennsylvanian	Minor	1.1	26,382,000	temporary 2.0
Pine Mountain	Minor		33,000	temporary 2.0
Post Oak	Minor	3.6	2,500,000	2.0
Potato Hills	Minor		49,000	temporary 2.0
Southwestern Oklahoma	Minor	2.3	2,754,000	temporary 2.0
Western Oklahoma	Minor		N/A	temporary 2.0
Woodbine	Minor	2.2	12,630,000	temporary 2.0

1 Bedrock aquifers with typical yields greater than 50 gpm are considered major.

Ogallala (High Plains)

The Ogallala aquifer, which exists in the Oklahoma Panhandle and western Oklahoma, is the most prolific aquifer in the state. Regionally, it is part of the High Plains aquifer that underlies 174,000 square miles in eight central states. In Oklahoma, the aquifer is comprised of the Tertiary-age Ogallala Formation, which consists of poorly-consolidated layers of sand, silt, clay, and gravel with intermittent well-cemented zones. These sediments were deposited some 3.8 million years ago by streams flowing out of the Rocky Mountains. The depth to water ranges from less than 10 feet to more than 300 feet. In 1998, the saturated thickness ranged from nearly zero to almost 430 feet, with the greatest saturated thickness occurring in eastern Texas County and northwestern Beaver County.



The Ogallala commonly yields 500 to 1,000 gpm, although some wells can produce up to 2,000 gpm in thick, highly permeable areas. In western Roger Mills and northern Beckham Counties, the Ogallala is partly eroded and thins to the east. Yields may be as great as 800 gpm in this area, but because of thinning and erosion of the formation, typical yields are about 200 gpm.

Most of the water pumped from the Oklahoma Ogallala aquifer is used to irrigate crops. The remainder is used for livestock (primarily cattle and swine), municipal, and domestic needs. Use of groundwater for crop irrigation expanded rapidly after 1946, due largely to the development of center pivots, leading to declines in groundwater levels and streamflows throughout much of the aquifer region. By 1998, water levels had declined more than 100 feet in local areas of Texas County and more than 50 feet in areas of Cimarron County. Today, groundwater is pumped out of the aquifer at a tremendous rate with more than half of withdrawals occurring in Texas County. In the Oklahoma portion of the Ogallala, 389,000 acre-feet of water was withdrawn in 1996-97, whereas only 175,000 acre-feet was replenished by recharge.

Water quality of the aquifer is generally very good and can be used for most purposes. In local areas, water quality has been impaired by high concentrations of nitrate. Some deep portions of the aquifer have elevated concentrations of calcium, chloride, sodium, and sulfate, which derive from upward movement of mineralized water from underlying Permian formations.

Roubidoux (Ozark)

The Roubidoux aquifer in Oklahoma is part of the larger Ozark aquifer in the Ozark Plateau's aquifer system, which extends into Arkansas, Kansas, Missouri, and Oklahoma. The aquifer is comprised of several geologic units of Ordovician and Cambrian age, consisting primarily of dolomite with some interbedded sandstone. The primary water-bearing units are the Gunter Sandstone, Roubidoux Formation (characterized by the highest well yields), and the Jefferson City and Cotter Dolomites. The thickness of the Roubidoux aquifer is variable ranging from zero, where the Precambrian granite outcrops in Spavinaw, to greater than 2,000 feet in parts of Cherokee and Sequoyah Counties. Average thickness of the aquifer is estimated to be 1,000 feet.

The Roubidoux aquifer is used as a source of water for municipal, agricultural, industrial, and domestic purposes. Yields of wells completed in the deeper portion of the aquifer range from less than 25 gpm to more than 1,000 gpm. The highest yielding wells are public water supply wells, most of which are in Ottawa County. Yields of shallower wells, completed primarily in the Cotter and Jefferson City Dolomites, range from less than 10 gpm to more than 300 gpm.

Overlying the Roubidoux aquifer is the Boone minor aquifer, which consists of Mississippian-age formations. Although wells producing from the Boone typically yield less than 10 gpm, the aquifer is an important source of water for domestic use in northeastern Oklahoma. The Boone aquifer is hydraulically separated from the Roubidoux aquifer by the Chattanooga Shale, which acts as a confining layer.

The primary source of recharge to the Roubidoux aquifer is infiltration of precipitation where the aquifer is exposed at the surface in southern Missouri and northeastern Arkansas. Generally, recharge from precipitation does not occur in the Oklahoma portion of the aquifer, which is overlain by younger rocks.

The chemical quality of water from the Roubidoux is suitable for most purposes but in some areas concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards. Dissolved solids concentrations range from less than 200 mg/L in the eastern portion of the aquifer to greater than 1,000 mg/L in the west and south. Sodium chloride (salt) water is present along the western and southern edges and at depth throughout the aquifer, making the water unsuitable for most uses. Large concentrations of gross-alpha radioactivity and radium-226 occur near the western edge of the aquifer and appear to be correlated with chloride concentrations.

Contaminated water from abandoned zinc and lead mines in Ottawa County has the potential to degrade the quality of Roubidoux water in the vicinity of Miami and Picher. Water in the abandoned mines has a low pH and contains high concentrations of sulfate, fluoride, cadmium, copper, iron, lead, manganese, nickel, and zinc.

Rush Springs

The Rush Springs aquifer, which occurs primarily in western Oklahoma, is comprised of the Permian-age Rush Springs and Marlow Formations. The Rush Springs Formation is a massive fine-grained poorly cemented sandstone with some

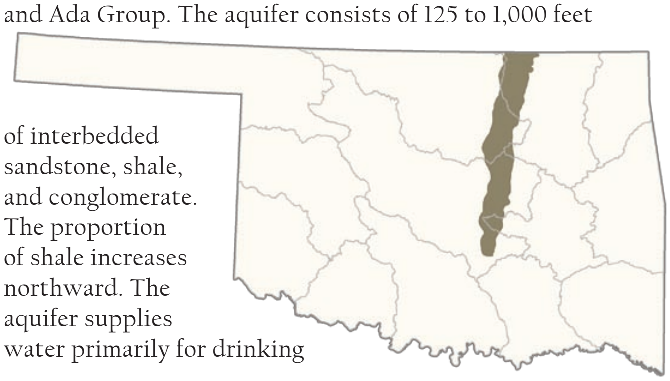
interbedded dolomite, gypsum, and shale. The Marlow Formation is composed of interbedded sandstones, siltstones, mudstones, gypsum-anhydrite, and dolomite. Water is not produced from the Marlow Formation as it acts as a confining unit that retards downward movement of the groundwater. Aquifer thickness ranges from less than 200 feet in the south to about 330 feet in northern areas and is generally less than 250 feet thick through the central part of the aquifer.

The aquifer is used primarily for irrigation, but it also supplies water for industrial, municipal, and domestic use. Most groundwater withdrawn from the Rush Springs aquifer is in Caddo County. Wells commonly yield 25 to 400 gpm while some irrigation wells are reported to exceed 1,000 gpm. Yields from the Marlow Formation are much smaller than from the Rush Springs Formation.

Water from the Rush Springs aquifer tends to be very hard yet suitable for most uses. Levels of dissolved solids are generally less than 500 mg/L. Nitrate, sulfate, and arsenic concentrations exceed drinking water standards in some areas, limiting its use for drinking water.

Vamoosa-Ada

The Vamoosa-Ada aquifer, located in east central Oklahoma, is comprised of the Late Pennsylvanian-age Vamoosa Formation and Ada Group. The aquifer consists of 125 to 1,000 feet



of interbedded sandstone, shale, and conglomerate. The proportion of shale increases northward. The aquifer supplies water primarily for drinking and other municipal purposes. Wells commonly yield 25 to 150 gpm, locally yielding as much as 300 gpm. The most prolific wells are in the Seminole area where they produce up to 500 gpm.

Although water quality is generally good in the Vamoosa-Ada aquifer, iron infiltration and hardness are problems in some areas. Chloride and sulfate concentrations are generally low. Except for areas of local contamination from past oil and gas activities, water is suitable for use as public supply.

Water Demand Projections

Projecting water demands 50 years into the future is a difficult task. Nevertheless, this is the foundational element of future water supply planning. The OCWP update utilized a conventional, yet innovative, methodology in forecasts prepared for OCWP water use sectors: Municipal and Industrial, Self-supplied Residential, Self-supplied Industrial, Thermoelectric Power, Crop Irrigation, Livestock, and Oil and Gas. A more detailed explanation of the methodology and data sources used for these forecasted demands is contained in the OCWP *Water Demand Forecast Report*.

A primary objective of this water plan update was to evaluate water supply and demand from a water basin or watershed level. However, initial water demand projections were assembled at the county level, consistent with available data. For purposes of comparing water demand to supply at the basin level, county-level demands were spatially distributed down to the basin level.

County-level demands (included in the Appendix) were developed as total water needs or water withdrawals and are inclusive of water lost or returned to the water cycle. Future weather conditions were assumed to be similar to those that impact current rates of water use for all demand sectors. The rates of use for each sector do not account for potential future improvements in water use efficiency and conservation beyond those currently in place. The potential implications of climate change and demand management (including conservation) are discussed elsewhere in this section and in the "Regional/ Statewide Opportunities and Solutions" section.

Municipal and Industrial (M&I) Demand

Approximately 92% of Oklahoma's residential population gets its water from a public supplier. M&I demands represent water that is provided by public water systems to homes, businesses, and industries throughout Oklahoma, excluding water supplied to thermoelectric power plants and agricultural water users. These demands were estimated on a county-level basis, and using a different methodology, developed at the individual water provider level. The quantity of water associated with system leakage, unmetered connections, and other unaccounted for water losses was estimated and included.

County-Level M&I Demand

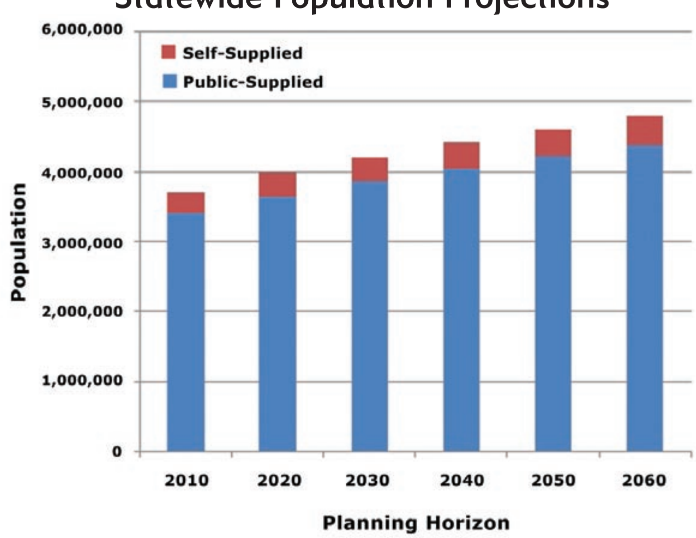
To forecast publicly-supplied M&I water demand with detail and accuracy, this sector is grouped into two sub-sectors—residential and nonresidential. Each sub-sector is estimated separately because households (residential) and businesses (nonresidential) are driven by different water use patterns and uses.

Public-Supplied Residential Demand: This sub-sector represents water supplied to residential households by public water supply systems that is used inside and outside the home for domestic activities. Indoor water uses include water for bathing, flushing, washing, drinking, and other indoor uses. Outdoor uses include water for landscape irrigation, car washing, recreation, domestic animal care, and similar purposes. The basic methodology developed for estimating future demands for this sector is based upon the average residential water use per capita times the projected population served within the county. County population projections, the primary driver for public-supplied residential water demand, were derived from a special unpublished tabulation compiled by the Oklahoma Department of Commerce (ODOC) for the OWRB in 2002. These projections, which include population counts by decade from 2000 to 2060, were updated by calibrating county-level projections to match 2007 Census estimates of population and adjusted to align with the most recent available data, such as information on military base realignments and anticipated casino expansions.

To estimate the population served by public water systems, a 2005 USGS report (including estimated population on private wells by county) was used to allocate the 2007 population projections between public-supplied and self-supplied residential sectors. The ratio of public-supplied to self-supplied population for each county is assumed to remain constant into the future.

The primary source of information for developing data on residential water use and water loss was the 2008 OCWP Public Water Provider Survey, which was distributed to 785 public water systems throughout the state. The survey collected data on annual water demand, residential service, and retail service area population for each provider in 2007. Information received from the surveys was used to derive an average residential per capita water use factor, or residential gallons per capita per day. A weighted average of this use was calculated for each county based upon serviced populations.

Statewide Population Projections



The survey also requested information on water losses and non-revenue water use, which was factored into residential water demand.

Public-Supplied Nonresidential Demand: Nonresidential refers to properties other than residential housing, such as office buildings, shopping centers, industrial parks, schools, churches, commercial businesses, and hotels. For purposes of the OCWP water demand forecast, the public-supplied nonresidential forecast captures water use from all nonresidential establishments other than those identified and represented in the self-supplied sector. Not included are establishments from the self-supplied industrial sector. Nonresidential water use by county is generally estimated by multiplying county employment by water use per employee.

The public-supplied nonresidential forecast is driven by economic activity, which for the OCWP was measured and forecasted utilizing employment projections developed by county and employment group. County-level employment data were based primarily on employment counts from the North American Industry Classification System (NAICS) obtained from the Quarterly Census of Employment and Wages (QCEW) Program. The most recent available Oklahoma Employment Security Commission (OESC) 10-year projections of statewide employment were used to project demands to 2016. Beyond 2016 (to 2060), employment was assumed to grow in direct constant proportion to county population projections. When more reliable information on future employment was available, it was used to adjust the employment projections.

Average water use per employee by NAICS was developed from the IWR-MAIN Water Demand Management Software, a demand model developed by the USACE's Institute for Water Resources. The nonresidential database contains average gallons of water use per employee per day at the 2-digit and 3-digit Standard Industrial Code. A special tabulation was computed to transform the data to 2-digit NAICS codes. The water use coefficients represent all water used at a given establishment on an average day divided by the number of employees.

M&I Demand: The total M&I demand is represented by simply combining the county public-supplied residential demand with the public-supplied nonresidential demand.

Provider-Level M&I Demand

Population and water demand projections, estimated for each of 785 water providers that were surveyed through the 2008 OCWP Water Provider Survey, will serve as a valuable planning tool for many Oklahoma systems, especially smaller towns and rural water districts that lack the necessary resources and information to compile their own projections. Forecasts for each public system are estimated from average water use (in gallons per capita per day) multiplied by each system's projected retail population.

Per capita water use information, collected through the survey conducted by the OWRB in cooperation with the Oklahoma Rural Water Association and Oklahoma Municipal League, was supplemented with available provider data from the OWRB and Oklahoma Department of Environmental Quality (ODEQ). Results included information on retail population served, annual average daily demand, total water produced, wholesale purchases and sales between providers, and estimated system losses. Each provider's average daily demand for 2007, excluding wholesale water sales to other providers, was determined to be the provider's retail service area demand. This demand, which included a system water loss factor, was divided by the retail population served in 2007 to determine each system's water demand in gallons per capita per day.

ODOC's special 2002 population projections by city and remainder of county were calibrated to 2007 Census estimates to establish population growth rates for cities, towns, and rural areas through 2060. Population growth rates were applied to 2007 population-served values for each provider to project future years' service area (retail) populations. The per capita water demand rate, which remains constant through time, is applied to projected population served values for each water provider to determine future water needs. Region-specific provider-level population and water demand projections, as well as wholesale water transfers and infrastructure needs, are presented in the OCWP Watershed Planning Region reports.

OCWP provider forecasts do not mirror county M&I demand. Provider-level forecasts rely primarily on the total amount of water provided to each provider's retail customers, including all nonresidential water use and water for power generation. County-level M&I demands were developed based upon: (1) a county-weighted average rate of water use and county-level population adjusted for the percent of county population served, (2) county employment by employment group multiplied by a water use factor per employee per day for each employment group, and (3) a county-weighted average percent system loss.

Self-Supplied Residential Demand

This sector includes demands for households on private wells that are not connected to a public water supply system. Most are located in city suburbs and rural areas of the state. While some self-supplied residential homes use well water for livestock care, this demand only represents water use inside the home and non-agricultural outdoor use.

Data used to develop the self-supplied residential forecast are similar to that used in the public supply residential forecast. USGS 2005 water use estimates for current population on private wells were used in conjunction with ODOC's growth rates to determine future population projections for the self-supplied sector. The average daily use of self-supplied households is assumed to be similar to that of public-supplied households in a given county. Thus, the county average residential per capita daily demand, as calculated for the public-supplied residential water demand sector, was used.

Self-Supplied Industrial Demand

Self-supplied industrial water demand typically represents large users that have access to their own supply source requiring a water use permit from the OWRB. These entities include sand companies, gypsum production plants, quarry mines, concrete producing plants, petroleum refineries, paper mills, sawmills, bottling and distributing plants, chemical plants, tire manufacturing plants, lime production, natural gas plants, and meat packing plants. This sector is important because it accurately captures demands from large water users that may be unique to Oklahoma.

Water use and employment data for this sector were obtained from OWRB annual water use reports. Employment data was subtracted from projections used in the public-supplied nonresidential forecast to avoid double-counting. Forecasts of self-supplied industrial demand used employment growth rates, according to industry type, that were developed for the public-supplied nonresidential sector. Similar to the public-supplied non-residential sector, the water use coefficients represent all use at a given establishment on an average day divided by the number of employees.

Thermoelectric Power Demand

The generation of electricity at thermoelectric power plants requires the use of water for cooling the equipment and condensing steam. Close-looped cooling systems, which are far and away the primary method of generation, require less water than that needed for once-through cooling. The OCWP included all thermoelectric power plants in the development of water demand for this sector, even though several power plants in Oklahoma receive water from municipal sources. (The M&I county-level forecast does not include water provided to thermoelectric power plants.)

Water demand estimates are based on megawatt-hours (MWh) produced by each plant and average water needs per MWh (assumed at 775 gallons). Information on monthly and annual power generation at each plant was obtained from the U.S. Department of Energy, Energy Information Administration. Average water need was based on a review of USGS 2005 water use data, unless substantiated by more detailed water use information. Power generation and water use is assumed to have a linear relationship into the future. According to reports from the U.S. Department of Energy, power generation is estimated to grow 1.1% annually during the next 30 years; this value is assumed for Oklahoma through 2060.

Agriculture Demand

Agricultural water demands represent a significant portion of statewide water withdrawals. For the OCWP, agriculture demands are estimated by two sub-sectors: livestock and crop irrigation. The U.S. Department of Agriculture (USDA) Census of Agriculture data were utilized for both.

Livestock Demand

Livestock demand is evaluated by livestock group (cattle, dairy cows, sheep, hogs, horses, and poultry) based upon average daily water requirements for each. The annual livestock water demand was calculated by multiplying the daily water requirement for each group by the number of livestock, then by the number of days in a year.

Census data from 1997, 2002, and 2007 were analyzed to obtain the highest reported number of livestock by livestock group in each county. The historical maximum was then assumed to be the build-out inventory for 2060 to allow for maximum future fluctuations due to unforeseen circumstances. Linear interpolation was applied to obtain the inventory for the forecast years between 2007 and 2060.

Crop Irrigation Demand

Forecasting irrigation water demand requires recognition of variable weather conditions, politics, and socioeconomic forces that can cause significant swings in cropping patterns, irrigation use, and ultimate water demand for irrigation. While numerous alternative scenarios could be developed, the OCWP adopted plausible guidelines representing a reasonable maximum demand for each county under average weather and current economic conditions (i.e., a base scenario).

Crop irrigation water demand for a given county is primarily driven by specific crop type, crop water requirements, number of acres planted, and type of irrigation system utilized. To estimate irrigation water demands, the chosen methodology utilized total irrigated acres times the weighted average crop irrigation water requirement per irrigated acre by county.

Data were obtained from the most recent available Agriculture Census on irrigated acres by crop type by county. These data were combined with crop irrigation water requirements, as published in the Natural Resource Conservation Service (NRCS) Irrigation Guide for Oklahoma. Adjustments were made to crop requirements to account for water losses from on-farm irrigation delivery systems. Water use efficiency and irrigation systems are assumed to remain at current levels. Projections through 2060 assumed historical maximum irrigated acres for each county. Demand projections for intermediate years were estimated using linear interpolation. The current mix of crops at the county level was assumed to remain constant and monthly demand patterns were estimated for each county according to the NRCS guide.

Oil and Gas Demand

Water required for the oil and gas industry was also projected by the OCWP. This sector includes water used in oil and gas drilling and exploration activities but does not include water used at refineries, which is included with industrial water demand.

Unconventional drilling techniques require more water use per completion than do conventional methods. For example, more water is required to penetrate shale deposits and access associated oil resources. Given the statewide variance in current drilling activities, water demands for the oil and gas industry are estimated by drilling type (or sub-sector): conventional, horizontal, and Woodford Shale. The basic methodology for estimating demands by drilling category utilizes the number of drilling activities times water used

Statewide Water Demand by Sector

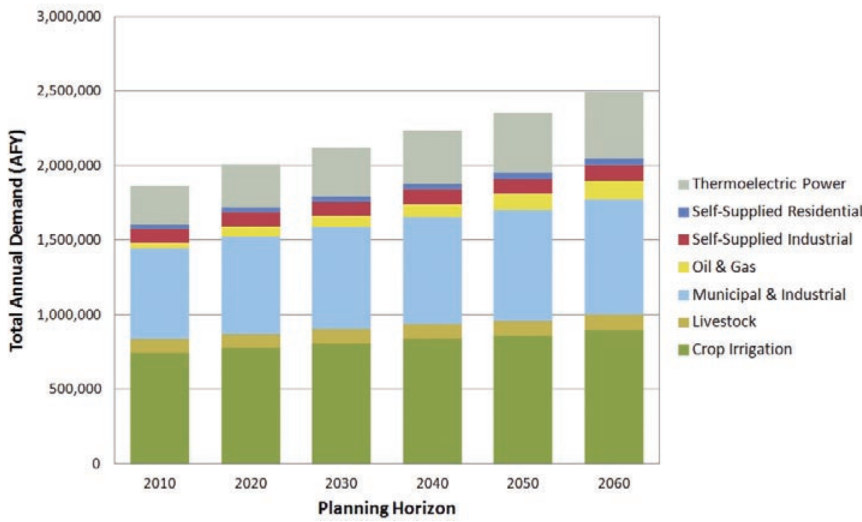
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	745,210	94,480	601,891	42,107	88,780	30,217	260,539	1,863,244
2020	775,661	95,792	647,038	74,403	87,558	32,610	290,660	2,003,721
2030	806,112	97,104	682,391	78,202	92,313	34,770	324,262	2,115,154
2040	836,562	98,416	713,982	90,080	96,730	36,863	361,750	2,234,382
2050	859,932	99,728	743,158	102,536	101,258	39,978	403,571	2,349,161
2060	897,464	101,040	772,773	115,570	105,683	41,155	450,227	2,483,912

Total demands will differ slightly from total basin/region demand due to delineation of county-level demand to the basin level.

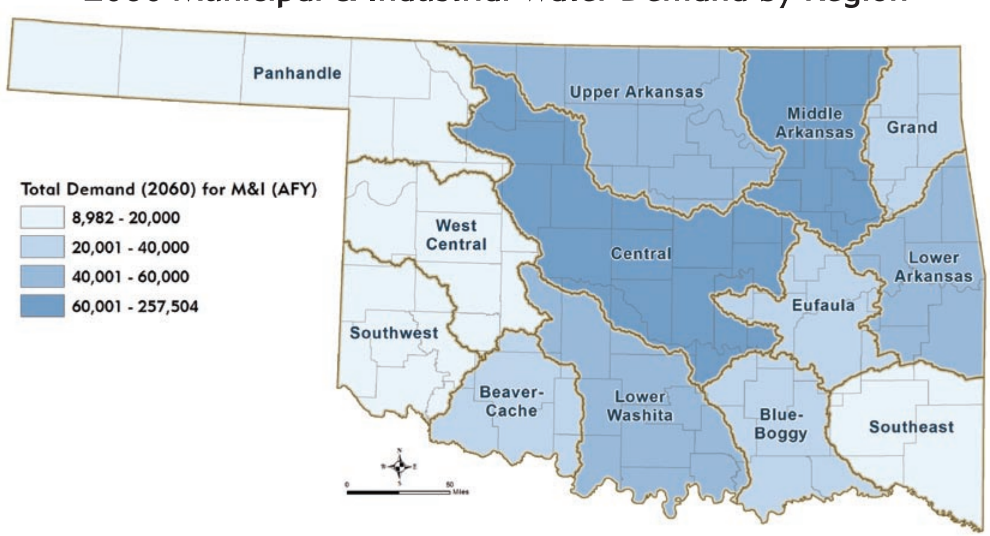
per activity in acre-feet. Sub-sector demands are then summed to estimate total demands from all oil and gas activities. For each sub-sector, an estimate of drilling activity in the future was developed using linear regression analysis coupled with data collected from the Oklahoma Corporation Commission and projections of drilling activities provided by representatives of the state's oil and gas industry.

The demand forecast developed in accordance with the O&G work group estimates that 2050 and 2060 demands in seven counties will drop below the 2010 demand level (due to Woodford Shale being played out). As a conservative approach, this assumption is not explicitly carried over into the Gap Analysis. Instead, basin demands are assumed to never fall below the 2010 base year demand levels, which is reflected in the Water Demand by Sector and Region tables.

Total Statewide Water Demand by Sector (AFY)



2060 Municipal & Industrial Water Demand by Region



Total Statewide Demand

Total water demand is projected to increase from almost 1.9 million AFY in 2010 to almost 2.5 million AFY in 2060. In 2010, crop irrigation accounts for nearly half (40%) of the total demand and M&I accounts for 32% of the water demand. Those percentages remain relatively constant throughout the forecast period. Demands include system losses from the public M&I and crop irrigation sectors and total withdrawals for thermoelectric power generation.

Basin- and Region-Level Demand

Basin-Level Demand

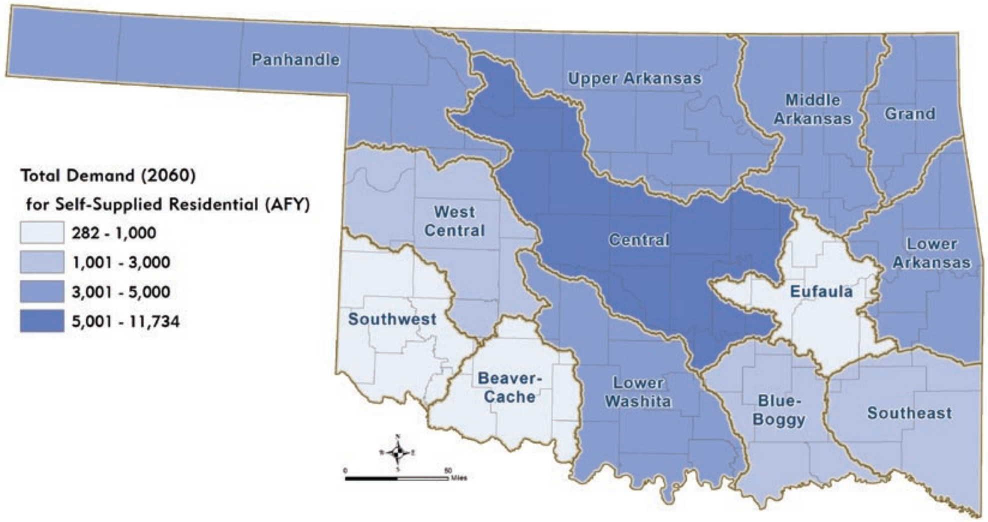
The following methodology was used to spatially distribute county-level demand to the OCWP's 82 basins. Basin demands were also aggregated to the region level as shown in the following 2060 Water Demand by Region figures to facilitate regional planning analyses and related activities. Total sector and statewide demands estimated at the county level will differ slightly from total sector and statewide demands estimated at the basin/region level due to the process of delineating county-level demand to basin-level demand.

M&I Demand: M&I water demand was allocated to providers using information from the ODEQ's Safe Drinking Water Information System (SDWIS) database and information from the 2008 OCWP Water Provider Survey. Incorporating this data with the OWRB's rural water systems (RWS) GIS database and municipal boundaries, demands were then allocated to OCWP planning basins. Demand for rural systems and municipalities was allocated to a basin based upon the percent of the RWS or municipality residing within the basin boundary.

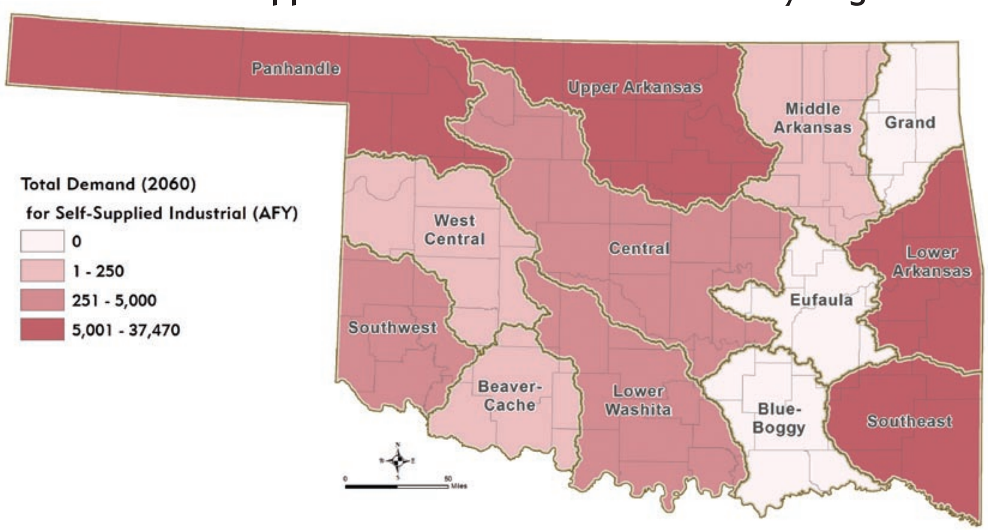
Self-Supplied Residential Demand: Self-supplied residential water demand was allocated to areas not serviced by a RWS or municipal provider. Within each county, the self-supplied demand was distributed uniformly across these self-supplied areas. County demand was then allocated to basins based upon the percentage of the self-supplied areas within a county that intersect a given basin. Total self-supplied residential basin demand was calculated by summing the fraction of that county-level demand falling within a given basin.

Self-Supplied Industrial and Thermoelectric Power Demands: Self-supplied industrial and thermoelectric power demands were determined for specific facilities. The demand of each facility was allocated to a given OCWP basin based upon the location of the facility's water use permit or the location of the facility itself if no permit information was available.

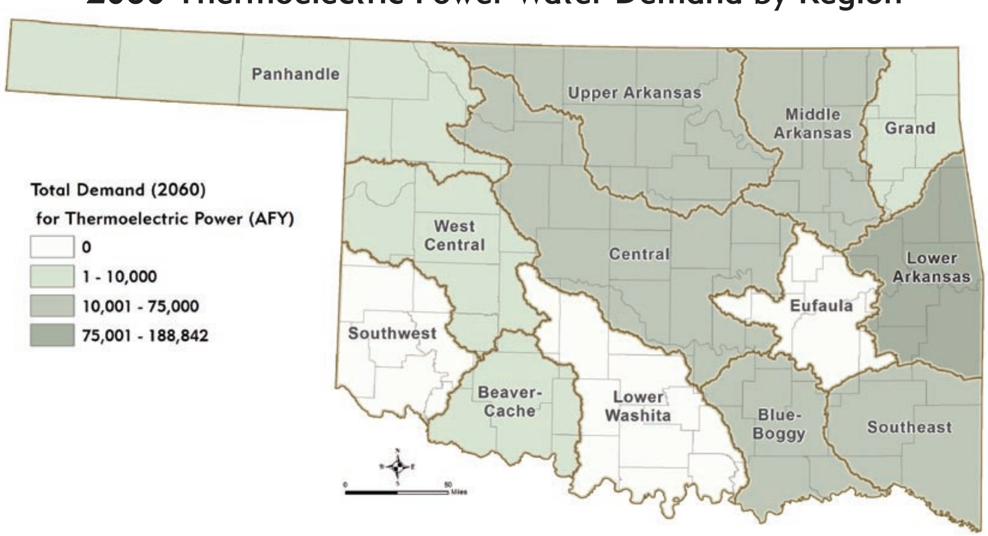
2060 Self-Supplied Residential Water Demand by Region



2060 Self-Supplied Industrial Water Demand by Region



2060 Thermoelectric Power Water Demand by Region



Agriculture (Crop Irrigation and Livestock) Demand: County crop irrigation demand was allocated to basins consistent with irrigated lands within each county. Irrigated lands were determined from the OWRB water rights database. The areas of use and dedicated lands associated with active permits for agricultural uses, based upon the Standard Industrial Classification (SIC) code, were combined to form an irrigated lands GIS shape file. Demand was evenly distributed across all irrigated lands in each county and allocated to basins according to the fraction of total irrigated area in the county that falls within a particular basin. Basin demand was calculated by summing the appropriate fraction of the county demand intersecting the basin area.

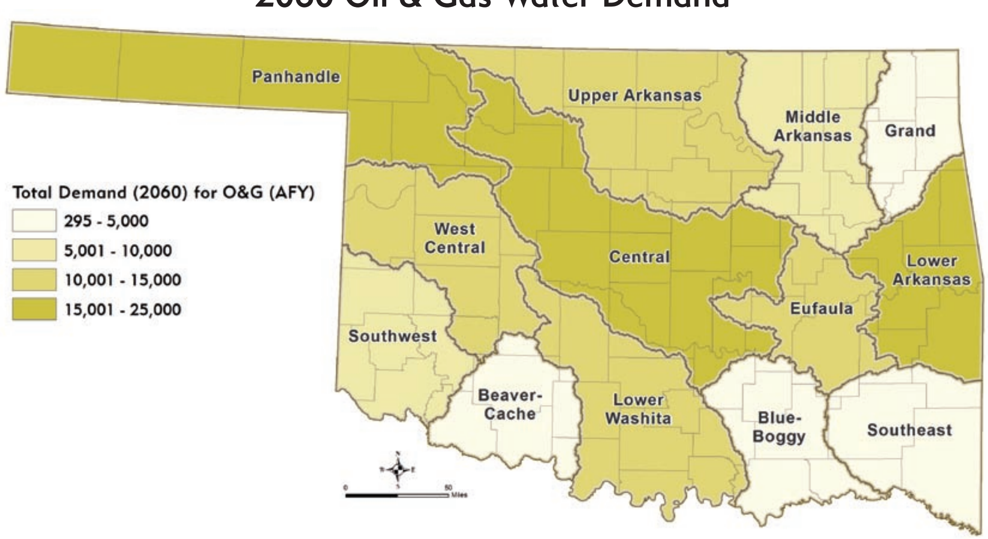
Livestock water demand was assumed to be distributed uniformly across each county. The county demand was allocated to basins based upon the fraction of the county within each basin.

Oil and Gas Demand: To allocate county-level oil and gas demand to planning basins, the OCWP used the appropriate ratio, according to source category (surface water, alluvial and bedrock groundwater), of total water granted under 90-day provisional temporary permits for oil and gas use from 2000 to 2008. County demand was assigned to each basin using the percentage of the county withdrawals that occurred in each basin based upon 90-day permits. Oil and gas current and future demand for surface water, alluvial groundwater, and bedrock groundwater was assumed to occur in the same proportions (location and quantity) as those permits.

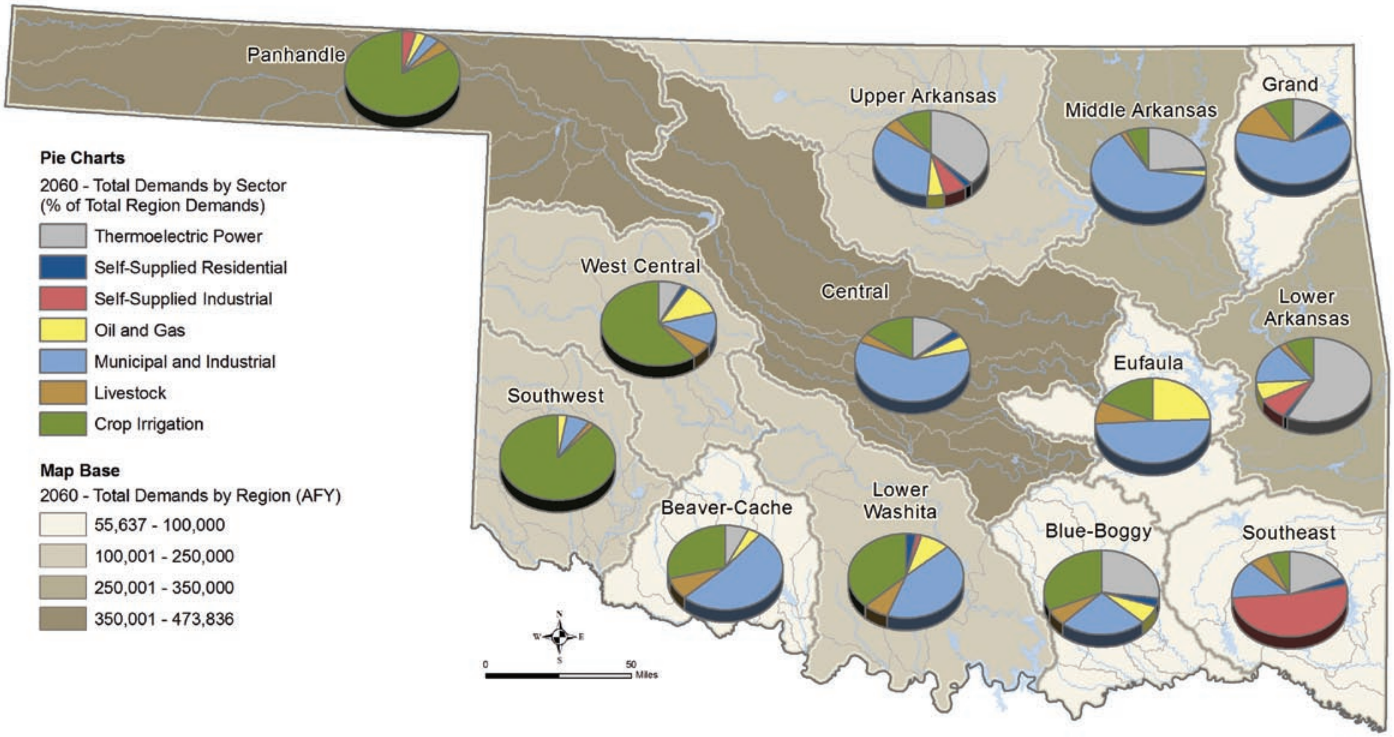
2060 Crop Irrigation Water Demand by Region

2060 Livestock Water Demand

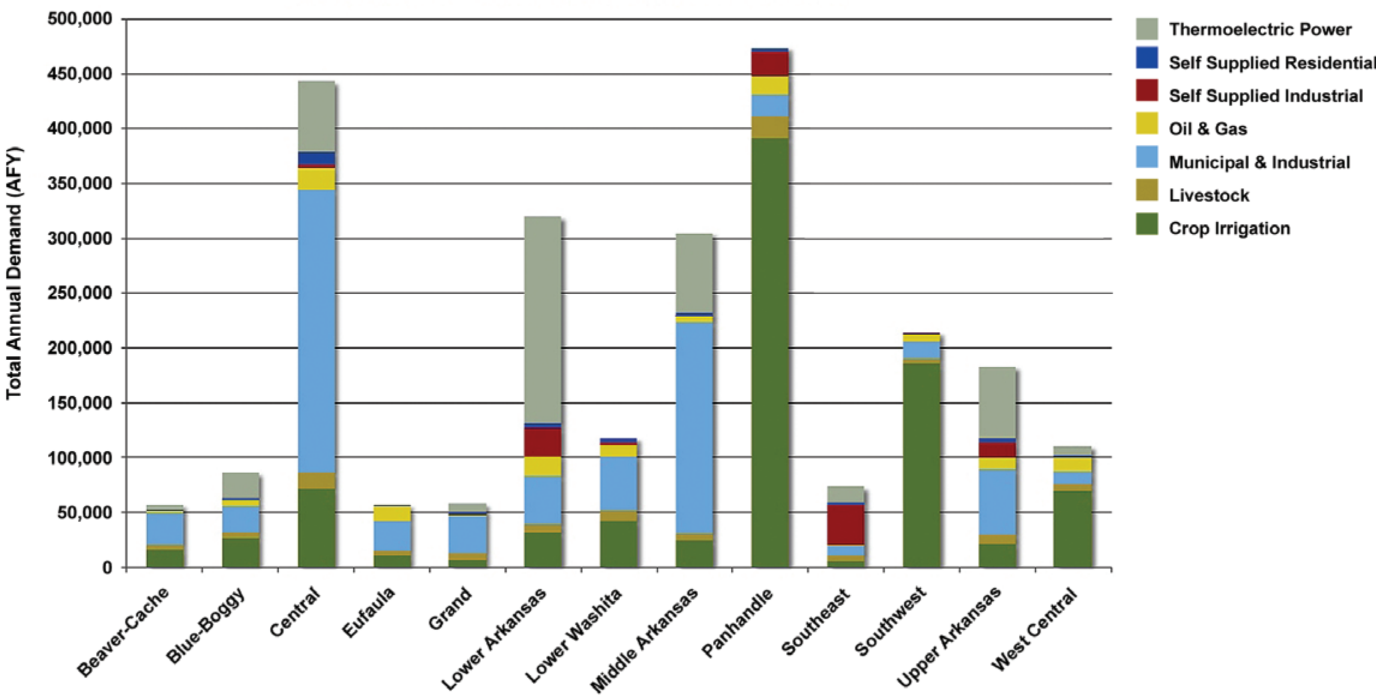
2060 Oil & Gas Water Demand



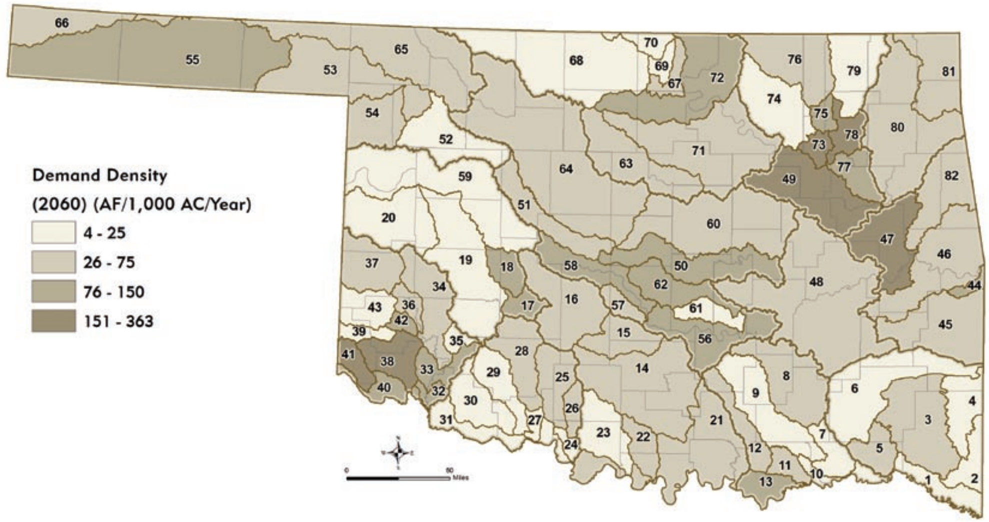
2060 Total Regional Water Demand & Water Sector Demand Distribution



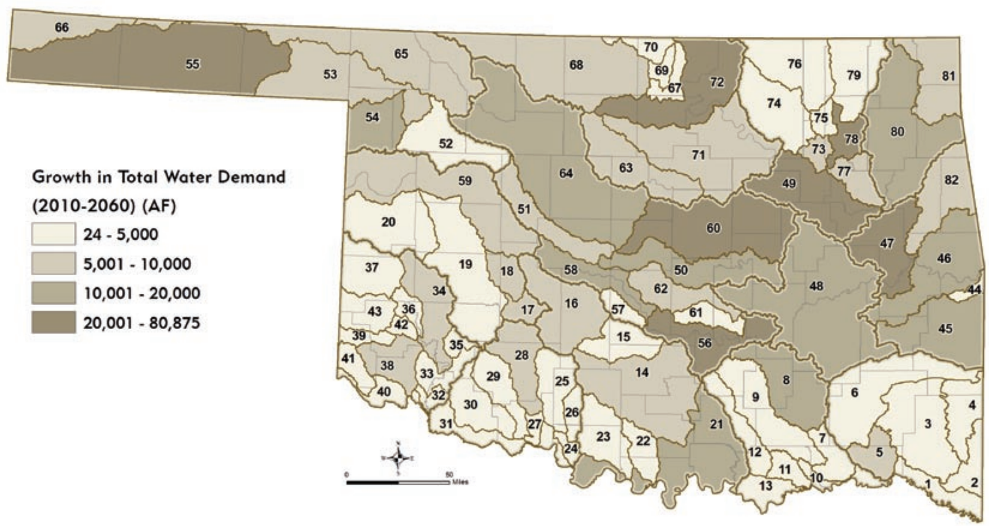
2060 Total Water Demand by Sector and Region



2060 Basin Water Demand Density



2010-2060 Growth in Total Basin Water Demand



Total Water Demand by Sector (page 1 of 3)

Beaver-Cache Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	12,390	3,910	24,600	550	200	370	2,570	44,590
2020	13,090	3,950	25,980	810	200	400	2,860	47,290
2030	13,780	4,000	26,970	1,120	200	410	3,190	49,670
2040	14,480	4,040	27,780	1,470	210	430	3,560	51,970
2050	15,010	4,090	28,480	1,890	210	440	3,980	54,090
2060	15,860	4,140	29,110	2,350	220	450	4,440	56,560

Blue-Boggy Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	20,140	4,680	16,340	5,390	0	1,520	13,320	61,390
2020	21,370	4,730	17,780	10,350	0	1,660	14,860	70,750
2030	22,600	4,770	19,250	7,450	0	1,800	16,570	72,450
2040	23,830	4,810	20,740	5,780	0	1,940	18,490	75,590
2050	24,770	4,860	22,280	5,460	0	2,090	20,630	80,090
2060	26,280	4,900	23,840	5,420	0	2,240	23,010	85,700

Central Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	58,100	13,850	208,390	7,100	2,420	8,680	37,100	335,640
2020	60,700	14,020	222,260	12,450	2,420	9,370	41,390	362,620
2030	63,290	14,190	233,370	12,900	2,510	9,990	46,180	382,430
2040	65,890	14,360	242,520	14,680	2,690	10,580	51,520	402,240
2050	67,880	14,530	249,970	17,240	2,870	11,140	57,470	421,100
2060	71,080	14,700	257,500	20,700	3,060	11,730	64,120	442,890

Eufaula Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	6,030	3,720	20,670	10,210	0	200	0	40,850
2020	6,910	3,780	21,970	19,570	0	220	0	52,440
2030	7,780	3,830	23,170	16,730	0	230	0	51,740
2040	8,650	3,880	24,470	16,290	0	250	0	53,540
2050	9,320	3,930	25,890	15,250	0	260	0	54,660
2060	10,400	3,980	27,360	13,610	0	280	0	55,640

Grand Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,430	6,320	22,060	70	0	1,920	4,490	37,300
2020	3,110	6,400	24,270	100	0	2,150	5,010	41,040
2030	3,780	6,480	26,560	140	0	2,360	5,590	44,920
2040	4,460	6,560	28,930	190	0	2,590	6,240	48,970
2050	4,980	6,630	31,380	240	0	2,830	6,960	53,020
2060	5,810	6,710	33,890	290	0	3,080	7,760	57,550

Total Water Demand by Sector (Page 2 of 3)

Lower Arkansas Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	26,370	6,980	30,460	2,130	23,820	2,840	109,280	201,890
2020	27,320	7,090	33,070	4,160	23,840	3,170	121,910	220,570
2030	28,270	7,190	35,750	6,700	23,940	3,510	136,010	241,370
2040	29,220	7,290	38,440	9,870	24,270	3,840	151,730	264,670
2050	29,950	7,400	41,160	13,640	24,970	4,180	169,270	290,580
2060	31,120	7,500	43,960	18,020	25,670	4,530	188,840	319,650

Lower Washita Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	29,100	8,320	31,770	5,970	2,000	3,270	0	80,440
2020	31,680	8,480	38,390	10,450	2,000	3,510	0	94,510
2030	34,250	8,630	40,940	9,610	2,010	3,680	0	99,130
2040	36,830	8,790	43,470	9,840	2,030	3,850	0	104,800
2050	38,810	8,940	46,190	10,330	2,060	4,020	0	110,360
2060	41,990	9,100	49,010	10,810	2,120	4,210	0	117,230

Middle Arkansas Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	19,500	6,190	157,080	1,350	110	2,520	41,910	228,660
2020	20,310	6,220	167,180	1,950	110	2,720	46,750	245,240
2030	21,130	6,260	175,200	2,660	110	2,880	52,160	260,390
2040	21,940	6,300	181,640	3,500	110	3,020	58,190	274,690
2050	22,560	6,330	187,280	4,450	120	3,150	64,920	288,810
2060	23,560	6,370	193,000	5,520	120	3,290	72,420	304,290

Panhandle Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	336,890	19,010	14,050	3,350	14,470	2,390	530	390,690
2020	347,680	19,220	15,180	5,150	14,490	2,540	590	404,860
2030	358,480	19,430	16,330	7,370	16,280	2,670	660	421,220
2040	369,270	19,640	17,390	10,020	18,400	2,780	740	438,250
2050	377,550	19,860	18,540	13,090	20,600	2,910	820	453,370
2060	390,860	20,070	19,630	16,580	22,740	3,030	920	473,840

Southeast Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,530	3,980	7,060	100	34,830	1,300	8,290	58,100
2020	3,120	4,060	7,490	170	34,840	1,380	9,250	60,320
2030	3,710	4,150	7,860	250	34,840	1,450	10,320	62,580
2040	4,300	4,230	8,220	350	35,420	1,510	11,510	65,560
2050	4,760	4,320	8,600	470	36,490	1,580	12,850	69,070
2060	5,490	4,400	8,980	610	37,470	1,650	14,330	72,930

Total Water Demand by Sector (Page 3 of 3)

Southwest Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Rural Residential	Thermoelectric Power	Total
	AFY							
2010	158,760	3,660	12,350	1,110	610	500	0	176,990
2020	164,000	3,760	13,060	1,850	610	540	0	183,820
2030	169,250	3,860	13,760	2,800	610	580	0	190,860
2040	174,490	3,960	14,440	3,940	640	610	0	198,090
2050	178,520	4,060	15,100	5,290	650	650	0	204,270
2060	184,980	4,160	15,770	6,840	670	690	0	213,110

Upper Arkansas Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	18,800	7,770	47,270	2,170	11,820	2,890	37,870	128,570
2020	19,290	7,900	50,200	3,330	12,360	3,110	42,250	138,450
2030	19,780	8,040	52,710	4,780	12,660	3,320	47,140	148,430
2040	20,270	8,180	55,120	6,500	12,970	3,520	52,580	159,140
2050	20,650	8,310	57,200	8,490	13,270	3,720	58,660	170,300
2060	21,260	8,450	59,340	10,760	13,590	3,910	65,450	182,770

West Central Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	54,160	6,090	9,800	2,610	20	1,820	5,180	79,680
2020	57,080	6,180	10,210	4,060	20	1,880	5,780	85,220
2030	60,000	6,280	10,530	5,690	20	1,940	6,440	90,900
2040	62,920	6,370	10,840	7,660	20	1,990	7,190	97,000
2050	65,170	6,460	11,120	9,950	30	2,040	8,020	102,780
2060	68,770	6,560	11,380	12,540	30	2,090	8,950	110,300

Water Availability

A reliable source of water supply not only depends upon having the water physically present for diversion and use but also possess the necessary water rights and adequate infrastructure to deliver water of adequate quality. Thus, a reliable water supply is contingent upon all of the following aspects, which were analyzed at both the statewide and basin level for the OCWP:

- Physical water supply availability or “wet water”;
- Permits or water rights to divert water from surface water or groundwater sources;
- Adequate water quality for the intended use; and
- Infrastructure to divert, treat, and convey the water.

Physical Supply Availability

The primary objectives of the physical supply availability analysis are to characterize statewide physical water supply availability through the 2060 planning horizon, compare these supply projections with demand projections, and quantify anticipated shortages in physical supply. This analysis was performed for the three supply sources: surface water, alluvial groundwater, and bedrock groundwater. The term “gap” refers to forecasted surface water shortages. “Depletion” refers to a forecasted groundwater shortage condition where demand will exceed recharge, thus resulting in a net reduction (often minimal) in aquifer storage. What follows is a description of those analyses, the results, and inherent limitations. Additional information regarding the projected timing, magnitude, and probability of projected shortages in each basin is provided in the OCWP Watershed Planning Region reports.

Physical Water Supply Availability Analysis

As a key foundation of the OCWP technical work, a sophisticated database and GIS-based analysis tool was created to compare projected water demand to physical supplies for each of the 82 OCWP basins. The “Oklahoma H2O” physical water supply availability tool was used to more closely examine demand and supplies, identify areas of potential physical supply availability constraints and water supply shortages, and identify feasible solutions.

The versatile Oklahoma H2O tool can specifically evaluate a variety of “what if” scenarios at the basin level as well as policy management scenarios. Recognizing that water planning is a dynamic process, the tool can also be updated as new supply and demand data become available. A more detailed discussion of the Oklahoma H2O tool and water supply availability methodology can be found in the OCWP *Physical Water Supply Availability Report*.

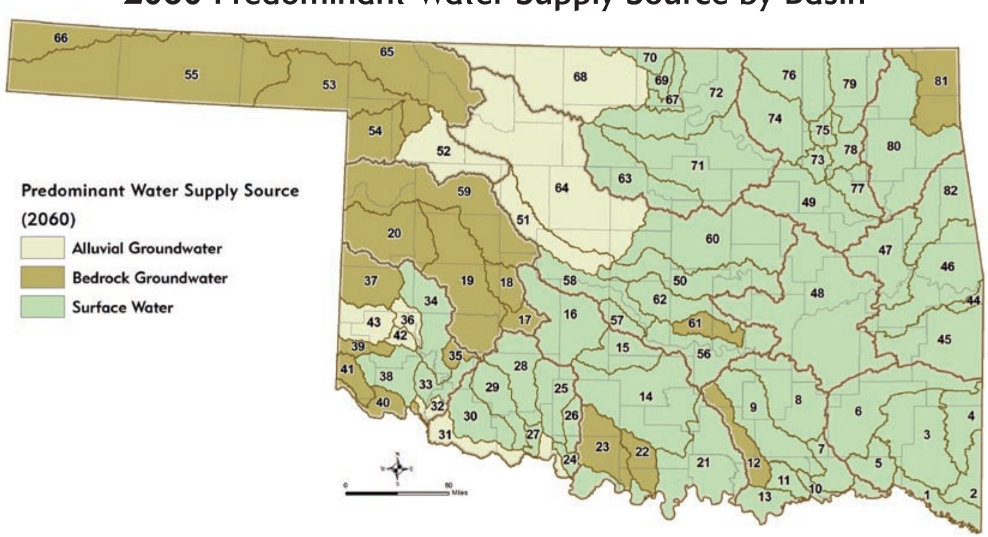
The primary inputs to the tool include demand projections for each decade through 2060. Supply inputs include surface water data for each of the 82 basins based on 58 years of daily streamflow gage data collected by the USGS. As such, these data explicitly include the historical drought of record for each basin. Groundwater resources were characterized using previously-developed assessments of aquifer storage and recharge rates. Aquifer-based data was distributed to the surface water basins to facilitate available water supply calculations.

Current demand, diversions, return flows, and alluvial groundwater/surface water interactions are physically manifested in the streamflow period of record. Oklahoma H2O takes those monthly streamflow data and subtracts out the projected monthly surface water and alluvial groundwater demand to estimate the amount of streamflow available in that future planning year. For bedrock groundwater, the analysis also compares monthly bedrock groundwater demand to monthly recharge rates.

Estimates of annual average and minimum annual surface water flow at each of the 82 OCWP surface water gages in 2060 are based upon flow data for the 58-year period of record at each OCWP stream gage location and projected surface water use in each basin. The minimum streamflow for each basin is an estimate of the minimum flow for that basin in any of the 58 years of historical hydrologic data, and as such, would likely not occur for all 82 basins in any single future calendar year. Surface water gaps are calculated through a monthly comparison (in monthly time steps) of surface water demand to gaged flow. Therefore, gaps may occur in any basin, including those for which minimum annual flows are projected to be greater than zero.

Alluvial groundwater aquifers have a hydrologic connection to overlying streams and rivers. Thus, the physical water supply availability analysis recognize that alluvial groundwater

2060 Predominant Water Supply Source by Basin



depletions can deplete associated surface water flows. The interaction of alluvial groundwater depletions and surface water flows is complex and changes depending on the location and rate of alluvial groundwater depletions and on the surface water flows themselves. Even so, alluvial groundwater demand from well pumping is, at some point in time, supplied by the flow in streams or from recharged water that would have been discharged to streams. For a more accurate estimation of future hydrologic conditions, this analysis incorporates the alluvial groundwater-surface water connection by attributing all alluvial groundwater demand to streamflow.

Bedrock groundwater aquifers in Oklahoma, for the most part, do not have a direct hydrologic connection to overlying surface water. Bedrock groundwater aquifers are replenished slowly by recharge from surface infiltration and/or from adjacent aquifers. This analysis evaluates bedrock groundwater depletions using projected bedrock groundwater demand in comparison to estimates of annual recharge. Depletions to bedrock groundwater aquifers are tabulated in comparison to estimates of the volume of water in storage. Even though frequent groundwater depletions are projected to occur, these depletions are generally minimal compared to the volume of water in storage. However, localized groundwater depletions may impact water quality, existing well production, and cause other adverse impacts for users.

The water supply availability analysis was done at a statewide screening level that includes several simplifying elements. Some of the primary considerations include the following:

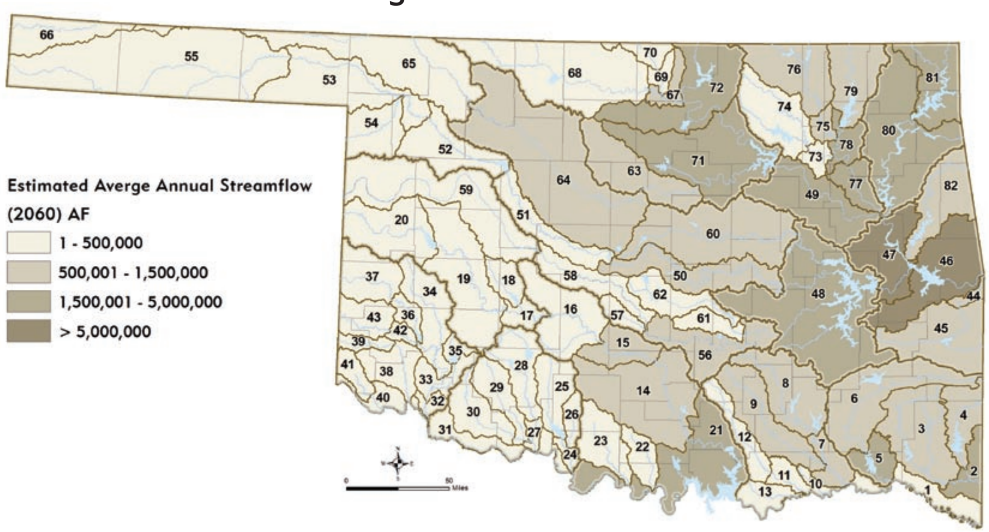
- Water rights or permit obligations and water quality are not constraining for purposes of the physical supply availability assessment.
- Nonconsumptive uses—such as recreation, navigation and environmental flows—are considered outside the physical supply availability assessment.
- Changes in groundwater aquifer volumes and water levels are not explicitly tracked (i.e., the tool does not calculate the water level of an aquifer at any future date).

Baseline Scenario

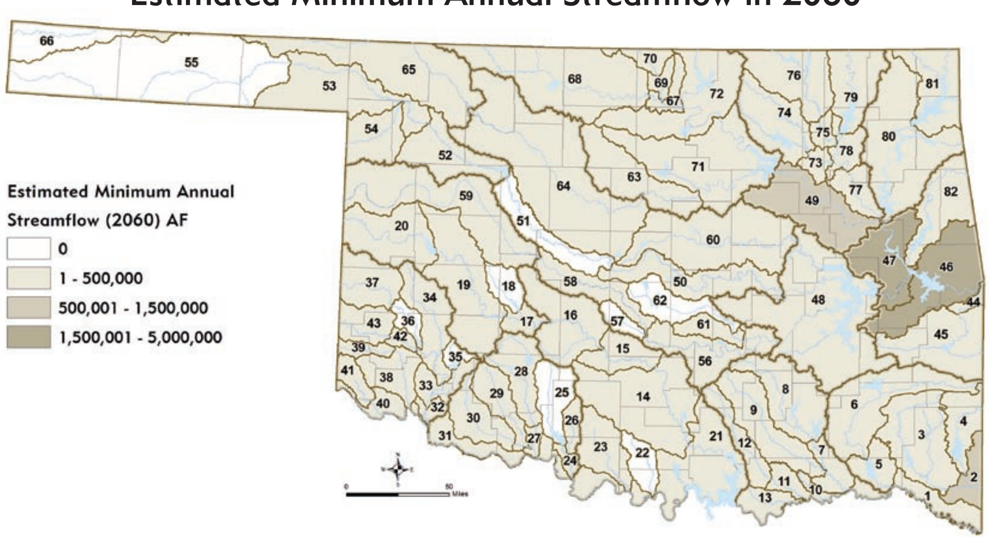
The Oklahoma H2O tool provides the ability to analyze any of a number of scenarios and potential future conditions. The following conditions were used to assess physical supply availability under the baseline scenario:

- The current proportion of sources for supplying existing demand (by basin and demand sector) will be used to meet future demand.
- In-basin local supplies and existing inter-basin transfers were used to satisfy the receiving basin's incremental demand (2010 to 2060) up to the permitted inter-basin transfer capacity.
- Return flows from a given basin's demand (e.g., M&I treated wastewater discharges) are delivered to the next downstream basin.

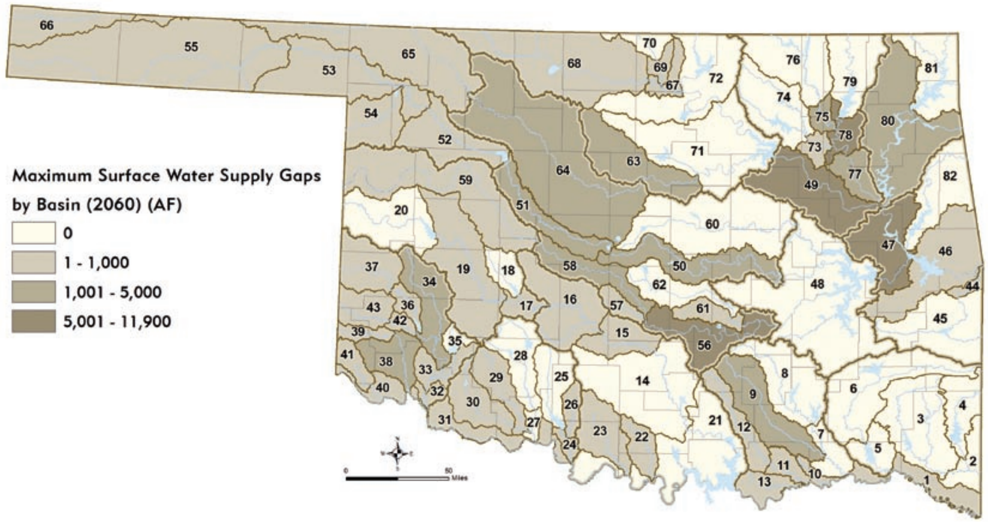
Estimated Average Annual Streamflow in 2060



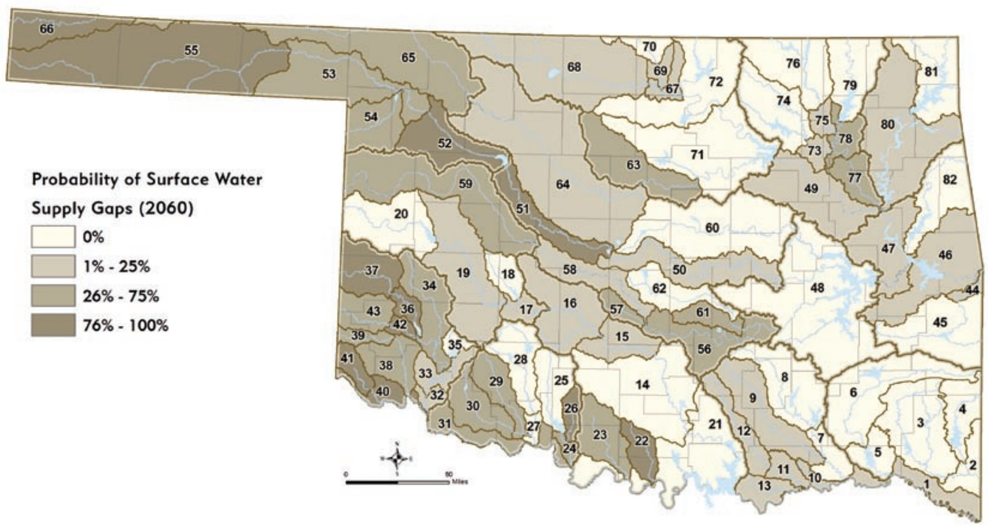
Estimated Minimum Annual Streamflow in 2060



2060 Maximum Surface Water Supply Gaps by Basin



Probability of Surface Water Gaps, 2060 Baseline Scenario



- The change in upstream demand affects the supply availability downstream. For example, return flows generated in a basin will continue to flow downstream until the supply is used.
- Supplies in bedrock groundwater aquifers are not hydrologically connected to surface water.
- Future demand is supplied by water from the basin that generates the demand (i.e., the gap is characterized as what would be expected to occur if all new demand were satisfied with local sources and existing inter-basin transfers).
- All effects of well pumping remain in the basin where a well is located.

A surface water gap occurs in any month where demand on surface water supply exceeds the basin's physically available surface water supply. The maximum annual surface water gap for the period of record is defined as the maximum of the sum of the monthly gaps for a given year. An alluvial groundwater or bedrock groundwater depletion occurs when the demand exceeds the aquifer recharge rate, at which point the demand draws supplies from aquifer storage and reduces the amount of water in storage. As mentioned previously, continued depletions will draw down stored supplies in the aquifer and may result in a situation where continued use of a well(s) is physically or economically infeasible.

The following results are not intended to indicate the permit or economic availability of water under Oklahoma's existing administrative system. Rather, these analyses focus on the physical availability of water supplies.

Physical Water Supply Availability Results

The baseline physical supply availability analysis for the OCWP 50-year planning period assesses the likelihood that sufficient amounts of surface water and groundwater supplies will be available to meet Oklahoma's future water demand. Specifically, baseline analyses portray the potential water shortages if local sources and existing inter-basin transfers are used to meet future demand, with local groundwater and surface water resources used in the same current proportions (albeit increasing quantities) to satisfy each demand sector's water needs in the basin.

As noted, the Oklahoma H2O tool can be used to generate results for various scenarios of future water supply conditions, such as the minimum, median, and maximum 2060 gaps and depletions projected for each supply source. For illustrative purposes and to indicate the worst case scenario for the baseline demands, the figures in this summary demonstrate the 2060 maximum gaps and depletions for each water supply source.

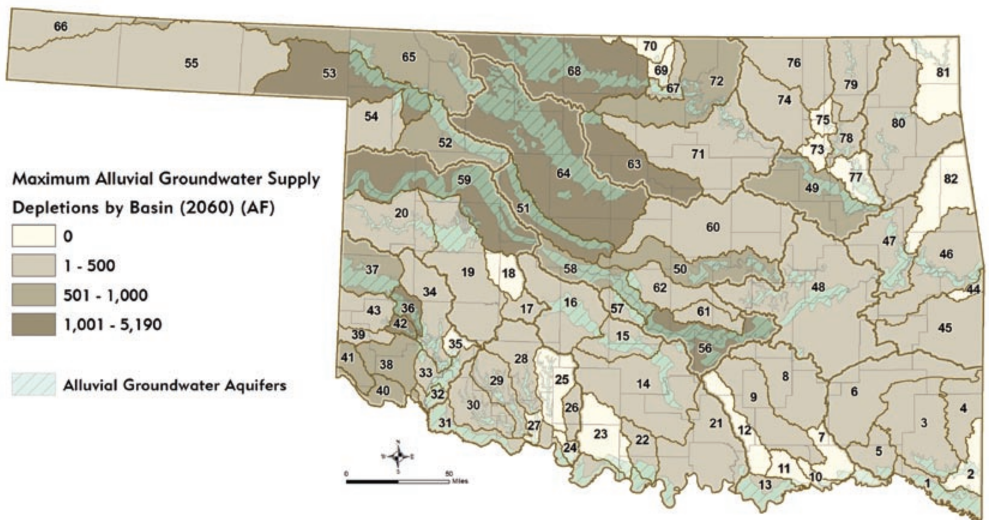
In addition to the magnitude of shortages, the probability of their occurrence is also an important consideration. The OCWP quantified both elements for surface water and alluvial groundwater. Bedrock groundwater recharge was assumed to be constant year round, so probabilities were not determined for that source. Many communities or water users would invest in infrastructure to mitigate shortages if they were anticipated to be high in both magnitude and probability. However, investments in infrastructure to mitigate a low-probability, high-magnitude shortage may not be considered economically feasible. Rather, such shortages might be better addressed through temporary demand management measures, such as outdoor watering restrictions during drought. Potential solutions for addressing anticipated supply needs are discussed in the "Regional/Statewide Opportunities & Solutions" section of this report and are addressed in more detail on the basin level in the Watershed Planning Region reports. The reports also present additional detail on the magnitude and probability of surface water gaps and groundwater depletions by basin and decade.

Limitations in the Analyses

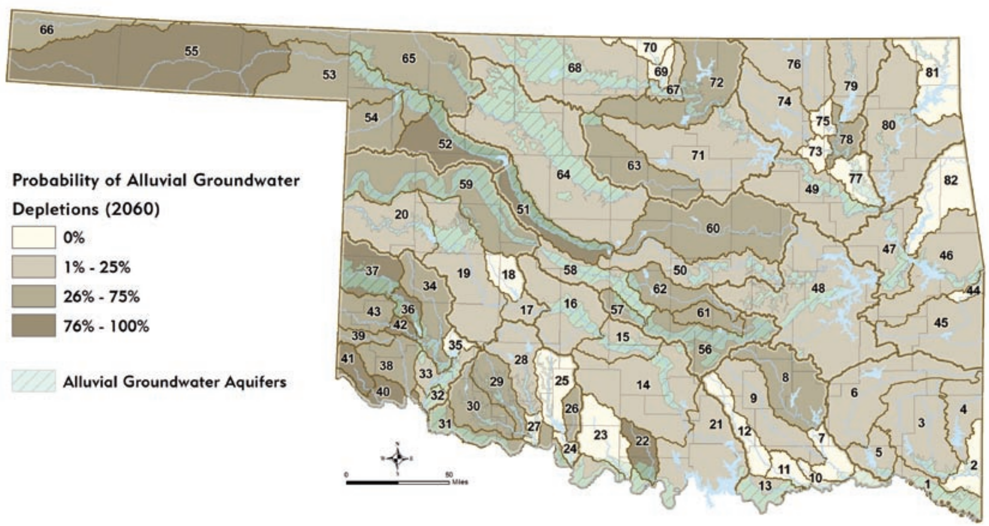
There are several known issues and uncertainties associated with the physical water supply availability methodology and input data. Key mitigating issues include the following:

- Highly localized surface water shortages or groundwater depletions may not be evident at the basin level; the magnitude and/or probability of localized shortages might be greater than those shown in this analysis for each OCWP basin.
- Future proportions of surface and groundwater used to satisfy future demand for a given basin and water use sector may differ from current proportions.

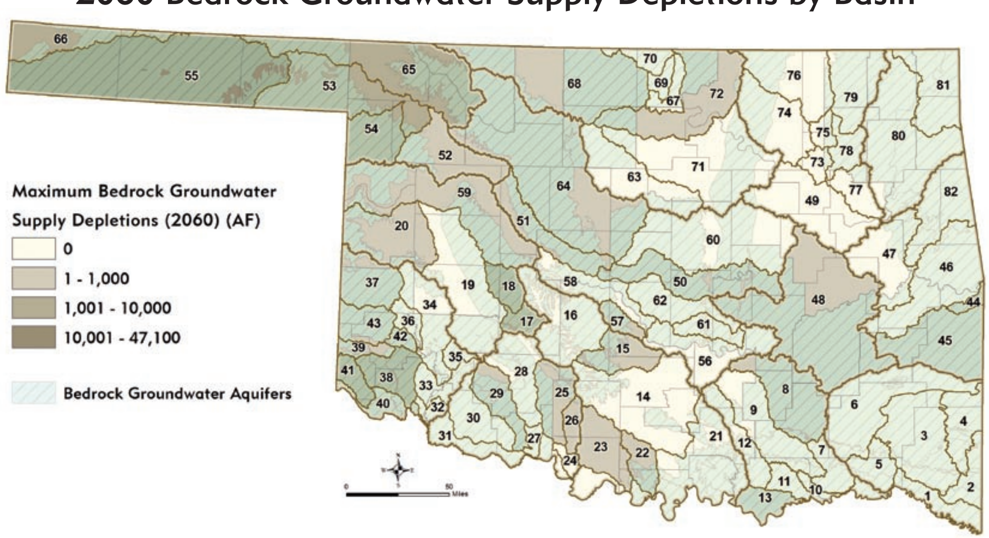
2060 Maximum Alluvial Groundwater Supply Depletions by Basin



Probability of Alluvial Groundwater Storage Depletions, 2060 Baseline Scenario



2060 Bedrock Groundwater Supply Depletions by Basin



- The Red River is not considered a water supply source due to high salinity and other issues.
- GRDA contracts are implicitly included in the input dataset using surface water diversion amounts identified in the OWRB water rights database.
- Drawing down the water in a reservoir may influence the timing or quantity of gaps, especially when the majority of consumptive use occurs upstream of the stream gage.
- Upstream states were assumed to use 60% of available flow into Oklahoma consistent with the OWRB's permitting protocol, which is adapted from interstate compact obligations between Oklahoma and its neighboring states.
- Downstream interstate compact obligations were assumed not to constrain physical availability and were analyzed separately as part of the permit availability analyses.

Permit Availability

The primary objectives of the statewide permit availability analysis are to characterize the water that can be made available through permits through the 2060 planning horizon, compare these estimates with demand projections, and quantify anticipated shortages from a permitting perspective. For this analysis, "permit availability" pertains to the amount of water that could be made available for withdrawals under water rights or permits issued in accordance with Oklahoma water law. [A water right can be a permit, prior right (groundwater), or vested right (surface water).]

Permit availability was evaluated in parallel with physical water supply, water quality, and infrastructure constraints. This section summarizes the results of the permit (or water rights) analysis associated with water supply availability in Oklahoma. A more detailed discussion of the analysis and methodology can be found in the OCWP *Water Supply Permit Availability Report*. The analysis consisted of the following aspects:

- Identification of the maximum amounts of surface water and groundwater that could be permitted under Oklahoma's existing statutory requirements and water rights permitting protocol.
- Consideration of interstate river compact agreements and obligations as they relate to permitting protocol and water availability.

The maximum amount of surface and groundwater available for permitting may change according to future statutory or rule changes. Tribal and federal reserved rights issues, which were also investigated and are discussed elsewhere in this *Executive Report*, could also affect the results of this analysis and should be considered. Additionally, the riparian rights doctrine, which is not evaluated in this report, could affect the findings as could future aquifer studies and resulting changes in maximum annual yields and equal proportionate shares (EPS).

The maximum amount of water that could be permitted was compared to demand forecasts for 2060 for each of the 82 OCWP basins to determine if the current permitting system posed constraints to meeting future demand. Interstate river compacts were also summarized as part of this effort, and Oklahoma's anticipated surface water development was compared to interstate river compact obligations to determine if compact requirements are likely to constrain the use of supplies to meet surface water demand. A detailed explanation of Oklahoma's water laws and associated permit requirements is presented in the "Water Management in Oklahoma" section of this report.

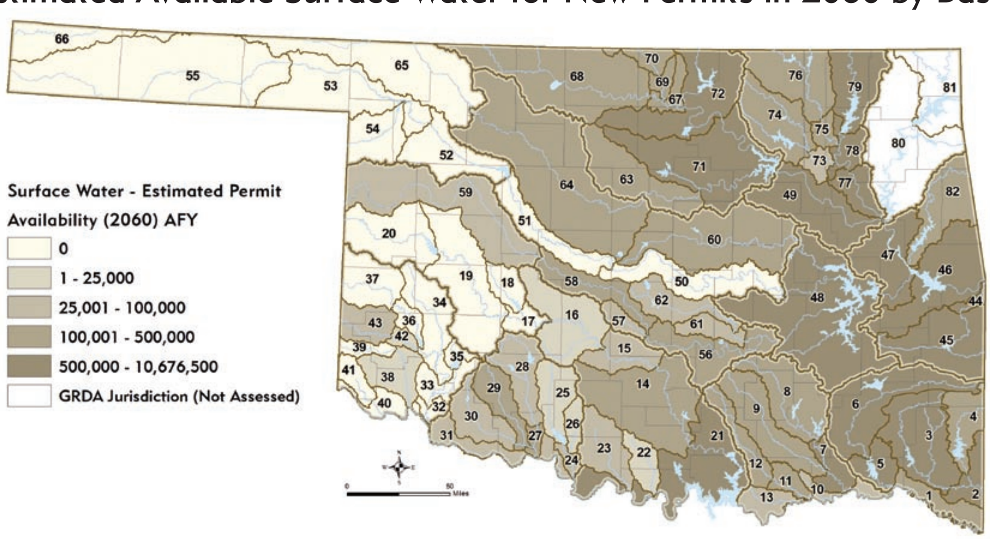
Surface Water Permit Availability

Surface water permit availability was determined for each OCWP basin. The impact of future surface water withdrawals on existing surface water rights could be minimal as they would be considered junior to existing water rights. Therefore, existing obligations, both upstream and downstream, were considered. Those obligations include existing active permits, potential future permits defined by OCWP demand projections, domestic water use, interstate river compact obligations (see following section), and reservoir dependable yields.

The quantity of surface water that would need to be permitted by 2060 to meet future demand was estimated for each OCWP basin utilizing the following methodologies that are consistent with OWRB surface water permitting protocol:

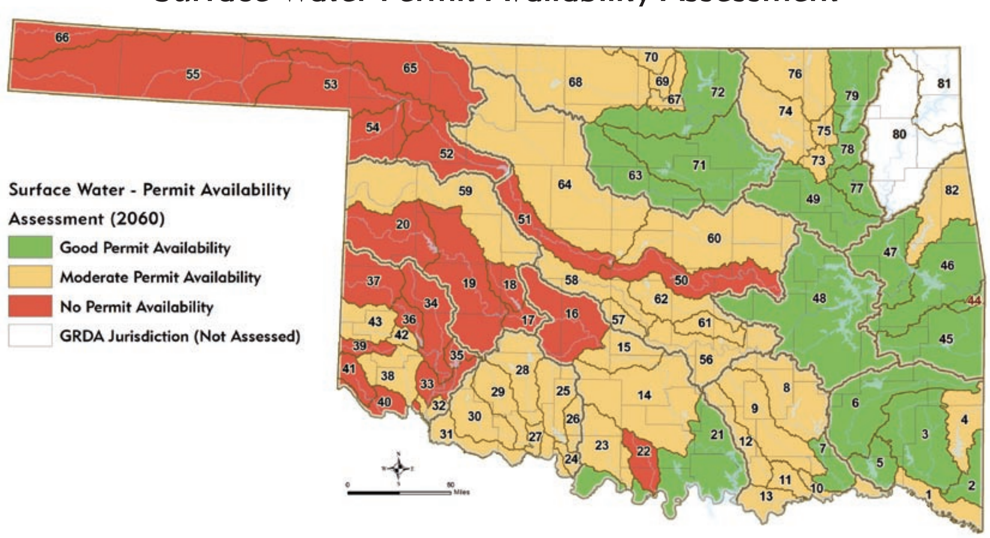
- Existing active rights were allocated to each basin by the location of the surface water withdrawal as indicated by the OWRB water rights database.

Estimated Available Surface Water for New Permits in 2060 by Basin



- The estimated surface water permits that will be required in 2060 were determined by summing the existing active surface water rights (annual quantity) and the increase in total surface water permit demand from 2007 to 2060, which was calculated from existing schedules of use and stream water demand projections. Since some existing rights are not currently fully utilized, the estimated 2060 stream water permit amounts may be greater than projected future demands and thus provides a conservative forecast.
- Active surface water rights were used to represent the current surface water amount that is unavailable for new permits. The OWRB regularly reviews permits to assure beneficial use and compliance with schedules of use.
- The increase in required surface water permits was calculated in two parts: projected increases in non-municipal and industrial demands, such as crop irrigation, and projected increases in M&I demands or existing schedules of use. Future surface water permits from non-M&I demands were calculated as the increase in non-M&I demand from 2007 to 2060 using current surface and groundwater supply proportions. Future surface water permits from M&I demands were calculated as the larger of (1) the increase in active permitted diversions due to schedules of use from 2007 to 2060, or (2) the increase in M&I demand from 2007 to 2060 using current surface and groundwater supply proportions in each basin.
- Oil and Gas users currently utilize 90-day temporary permits for most well drilling and development activities. For consistency, these activities were assigned a general permit in the analysis where the general permit amount is equal to the sum of the 90-day permits for the year.
- Upstream and downstream rights were included as permit obligations for each basin. The OWRB applies case-by-case analyses when permitting on the mainstem of a river, which includes the OCWP basin's outlet. To systematically account for mainstem permitting on a statewide basis, all upstream basins were taken into account. The immediate downstream basin was included in the basin's permit obligation. Permit availability gaps due to downstream basins' estimated future permits were flagged as a mainstem restriction.
- Domestic uses were calculated as six AFY per quarter section (160 acres) of the total basin area. Nonconsumptive uses were not incorporated in the analysis, consistent with current law and permitting practice.
- Consistent with OWRB methodology and interstate stream compact apportionment provisions, upstream states are typically recognized to be able to use 60% of the measured historical streamflow at the Oklahoma border. However, actual compact provisions are reviewed on an ad hoc basis for potential availability issues. The presumed reduction in flow is then accounted for in all downstream basins within Oklahoma.
- Arkansas was allocated (for purposes of this report) 40% of runoff generated in Basins 46 and 47, except the Lee Creek watershed, based on the Arkansas-Oklahoma Arkansas River Compact. Runoff was calculated as the measured stream flow. This is a conservative approach because return flows from uses in the basin can result in higher measured flows. Also based on this Compact, Oklahoma has free and unrestricted use of the runoff generated in Basins 44, 45, and 82, so no flow from these basins was recognized for Arkansas.
- For purposes of this report, the downstream State of Arkansas on the Red River was allocated 40% of runoff generated in applicable portions of Basins 2, 3, and 4 (below Broken Bow Lake, Pine Creek Lake, and proposed Lukfata Reservoir). Portions of Basins 3, 4, 5, 7, 11, and 13 upstream of the prescribed reservoir or proposed reservoir sites were excluded from the runoff allocations because the Red River Compact provides that Oklahoma has free and unrestricted use of such water. Runoff was calculated as the measured streamflow. This methodology is a simplification of compact apportionment provisions and others that provide the amount of runoff required downstream from Basin 1 and portions of Basins 5, 7, 10, 11, and 13, which may change during times of low flows in the Red River. The Compact has its own definitions of "runoff" and "undesignated flow" for apportionment provisions.
- Reservoir dependable yields used in this analysis, which were obtained from the OWRB water rights database, reflect all reservoir conservation pool allocations (irrigation, water quality, water storage, etc.). These yields and associated permits were not double-counted.

Surface Water Permit Availability Assessment



- NRCS reservoirs without dependable yields were included based upon their normal storage volumes. NRCS reservoirs and associated permits were not double-counted. Permits were associated with NRCS reservoirs within a half mile of the dam location.
- Estimated upstream future permits were accounted for in all downstream basins.
- Permit availability was not analyzed for GRDA's area of responsibility (Basins 80 and 81).

For each basin, the estimated 2060 surface water permit need was subtracted from average annual measured historical streamflow (adjusted by presumed compact constraints) to determine the surface water permit availability gap. Average annual streamflow (using data from 1951 through 1980 per OWRB protocol at the time of this analysis) was determined from the monthly surface water supplies calculated separately in the physical supply availability analysis.

Estimated permit availability represents the surface water that could be permitted in a given basin after satisfying existing permits and schedules of use and after satisfying the amount of new permits that would be needed to accommodate the basin's projected growth in surface water use from 2010 through 2060. New permits to accommodate the projected growth in surface water use were assumed to be required only to the degree that existing rights and schedules of use cannot accommodate the projected 2060 surface water use.

Results show that there is sufficient available surface water permit capacity in the majority of planning basins in 2060. In other words, projected surface water demands in 2060 (assuming continued use of current supply proportions of surface water and groundwater sources) could be fully permitted under current law and permitting protocol. Shortages in available water permits (insufficient permitted water availability for projected 2060 demands) are forecasted in 22 of the 82 OCWP basins. Shortages begin in the first year of the analysis (2010) in 19 of these basins.

<u>Interstate Stream Compacts</u>

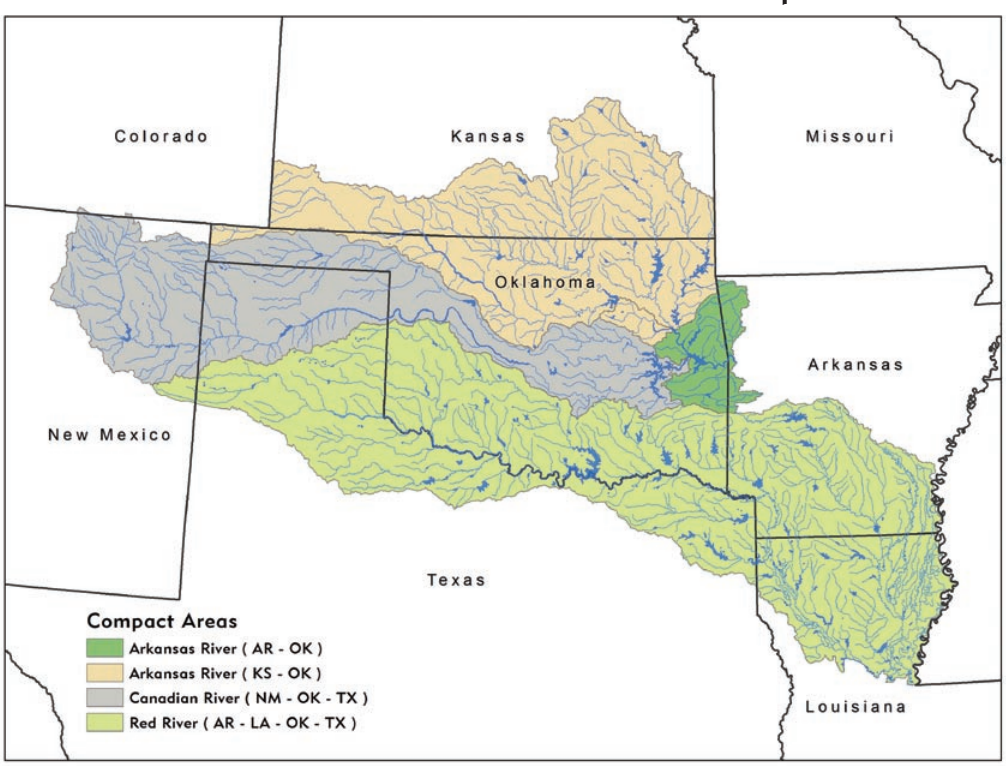
Interstate stream compacts to which Oklahoma is a party were evaluated to assess the potential for projected water needs and water development through the 50-year OCWP planning period. These compacts are formal written agreements between two or more states to divide or share the waters of a river that flows in each of the states. The compact must be approved by the legislatures of each state and approved by the U.S. Congress so that it becomes an enforceable statute in each state as well as federal law.

The benefits of entering into a compact vary, but the overriding benefit is to provide certainty to each state on what it can do to fairly develop and use shared waters, including future development as future demand may dictate. Compacts contain obligations as to how water may be diverted and stored for use in each member state while allowing remaining flows to pass downstream. Often, annual accounting by a compact commission is required to determine the amount of water used under the compact and subsequent compliance with the compact.

The OCWP *Water Supply Permit Availability Report* discusses each of the four compacts in more detail and presents the apportionment to each state and the operation and accounting under each compact commission. Development of additional water supplies to meet current and future demand does not appear to be constrained by Oklahoma's compact participation. Additional development in western Oklahoma is constrained by the typically limited physical water supply in the Canadian and North Canadian Rivers. Likewise, the potential for additional development on the Red River in southwestern Oklahoma appears to be more limited by water quality and physical supply than provisions of the Red River Compact.

In central and eastern Oklahoma, where precipitation and runoff are greater and where considerable water flows into the state from Kansas and Arkansas, compacts on the Arkansas and Red River do not impose apparent limitations on developing additional water supply projects to meet current or future water demand. Constraints to development are at

Oklahoma's Interstate Stream Water Compacts



least partially due to water quality issues, especially related to salts and total dissolved solids and costs associated with adequate water treatment.

Excess & Surplus Water

By statute, the OCWP analysis is required to include a definition of "excess and surplus water of this state" and a recommended procedure for determining specific quantities of that water "… to ensure that the area of origin will never be made water deficient." Utilizing a calculation procedure developed by the OWRB, which is presented in more detail in the "Policy Recommendations and Implementation" section of this report, the OCWP fulfilled this mandate for each of the 82 OCWP planning basins (i.e. areas of origin).

The initial calculation considers the total surface water permit availability amount minus the amount of annual anticipated surface water permits in 2060, as determined through the OCWP water demand study (Result A). In addition, the calculation includes an in-basin reserve equating to 10% of the total surface water permit availability plus 10% of the annual anticipated surface water permits in 2060 (Result B). The Excess/Surplus Water amount equals Result A minus Result B. Groundwater supplies are not included in the calculation. In future OWRB determinations of excess and surplus water available for out-of-basin transfer, only individual water use permit applications requesting more than 500 acre-feet of water will be considered. Also excluded from future consideration is any water reserved for Federal or Tribal rights and water reserved for instream or recreational flow needs.

It should be noted that "annual anticipated surface water permits in 2060" includes current and future anticipated permit needs, reservoir yields, existing out-of-basin transfers, downstream future permit needs (one basin downstream), a domestic use set-aside, and compact obligations. Furthermore, because OWRB permitting protocol provides the basis of this calculation and surface water use in the Grand Region is under jurisdiction of the Grand River Dam Authority, excess and surplus water was not calculated for Basins 80 and 81.

The accompanying tables and charts detail the results of the OCWP basin excess/surplus water analysis, organized by Watershed Planning Region.

Excess/Surplus Water Estimation (1 of 2)

Basin #	Region	Estimated Surface Water Permit Availability	Anticipated Surface Water Permits in 2060	In-Basin Reserve Amount	Estimated Excess/ Surplus Water
		AFY			
24	Beaver-Cache	122,395	72,633	19,503	30,259
25	Beaver-Cache	70,962	66,433	4,528	0
26	Beaver-Cache	33,187	26,425	5,961	800
27	Beaver-Cache	261,993	105,466	36,746	119,781
28	Beaver-Cache	101,290	70,664	17,195	13,431
29	Beaver-Cache	145,199	39,246	18,445	87,508
30	Beaver-Cache	79,568	46,048	12,562	20,958
31	Beaver-Cache	69,101	14,056	8,316	46,729
7	Blue-Boggy	1,170,866	273,322	144,419	753,125
8	Blue-Boggy	584,562	220,586	80,515	283,461
9	Blue-Boggy	435,401	119,005	55,441	260,956
10	Blue-Boggy	87,760	44,165	13,193	30,403
11	Blue-Boggy	275,776	79,568	35,534	160,674
12	Blue-Boggy	191,803	51,231	24,303	116,268
13	Blue-Boggy	131,493	52,941	18,443	60,109
50	Central	409,369	652,383	0	0
51	Central	112,370	429,659	0	0
56	Central	874,832	573,519	144,835	156,479
57	Central	39,109	7,569	4,668	26,872
58	Central	475,238	296,956	77,219	101,062
60	Central	483,939	357,284	84,122	42,533
61	Central	197,523	142,079	33,960	21,484
62	Central	97,692	53,199	15,089	29,404
64	Central	624,919	293,752	91,867	239,301
48	Eufaula	3,264,549	1,462,177	472,673	1,329,699
80	Grand[1]	---	---	---	---
81	Grand[1]	---	---	---	---
44	Lower Arkansas	1,411,082	448,634	185,972	776,477
45	Lower Arkansas	1,340,437	361,067	170,150	809,219
46	Lower Arkansas	21,496,845	10,890,177	3,238,702	7,367,965
47	Lower Arkansas	18,750,224	9,871,952	2,862,218	6,016,055
82	Lower Arkansas	968,460	797,585	170,874	0
14	Lower Washita	830,278	569,735	140,001	120,542
15	Lower Washita	426,061	398,857	27,205	0
16	Lower Washita	321,070	321,773	0	0
21	Lower Washita	1,509,406	642,687	215,209	651,509
22	Lower Washita	22,700	18,231	4,093	376
23	Lower Washita	99,481	17,287	11,677	70,518
49	Middle Arkansas	5,515,704	2,563,271	807,898	2,144,536
73	Middle Arkansas	404,051	314,056	71,811	18,185
74	Middle Arkansas	340,631	132,175	47,281	161,175
75	Middle Arkansas	761,721	500,602	126,232	134,887
76	Middle Arkansas	704,775	312,340	101,712	290,724
77	Middle Arkansas	3,186,776	1,952,161	513,894	720,721
78	Middle Arkansas	3,034,680	1,636,514	467,119	931,047
79	Middle Arkansas	1,827,148	1,203,905	303,105	320,138
52	Panhandle	111,641	358,697	0	0
53	Panhandle	118,363	236,997	0	0
54	Panhandle	38,937	77,064	0	0
55	Panhandle	64,531	173,752	0	0
65	Panhandle	110,327	247,278	0	0
66	Panhandle	16,282	88,906	0	0
1	Southeast	368,830	163,577	53,241	152,012
2	Southeast	2,439,917	510,599	295,052	1,634,266
3	Southeast	1,150,039	197,602	134,764	817,673

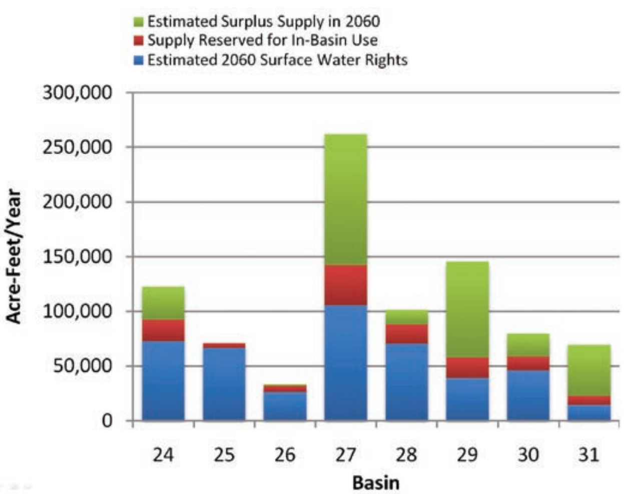
Excess/Surplus Water Estimation (2 of 2)

Basin #	Region	Estimated Surface Water Permit Availability	Anticipated Surface Water Permits in 2060	In-Basin Reserve Amount	Estimated Excess/ Surplus Water
	AFY				
4	Southeast	896,506	412,765	130,927	352,814
5	Southeast	1,527,953	269,335	179,729	1,078,888
6	Southeast	1,205,284	337,399	154,268	713,617
32	Southwest	254,683	257,243	0	0
33	Southwest	248,665	257,975	0	0
34	Southwest	199,971	248,024	0	0
35	Southwest	12,993	32,582	0	0
36	Southwest	49,280	188,400	0	0
37	Southwest	85,291	152,876	0	0
38	Southwest	113,629	104,784	8,845	0
39	Southwest	61,836	101,712	0	0
40	Southwest	11,424	18,317	0	0
41	Southwest	12,826	18,317	0	0
42	Southwest	77,287	70,540	6,746	0
43	Southwest	67,698	33,143	10,084	24,471
63	Upper Arkansas	833,256	378,134	121,139	333,983
67	Upper Arkansas	918,394	669,407	158,780	90,207
69	Upper Arkansas	383,575	215,915	59,949	107,711
70	Upper Arkansas	355,628	218,104	57,373	80,151
68	Upper Arkansas	490,430	209,448	69,988	210,994
71	Upper Arkansas	5,171,927	2,259,350	743,128	2,169,449
72	Upper Arkansas	3,636,822	1,790,594	542,742	1,303,486
17	West Central	217,040	253,565	0	0
18	West Central	16,369	44,782	0	0
19	West Central	183,288	210,283	0	0
20	West Central	89,300	188,319	0	0
59	West Central	242,631	212,095	30,536	0

1 Due to GRDA jurisdiction, excess/surplus water was not calculated for basins in the Grand Region.

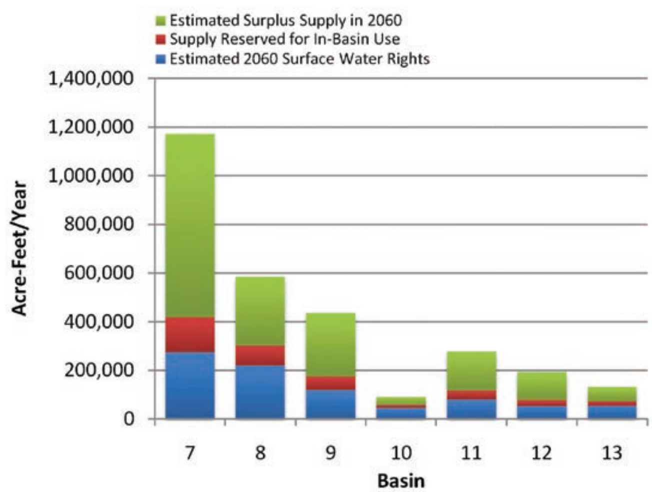
Estimated Surface Water Surplus in 2060

Beaver-Cache Region

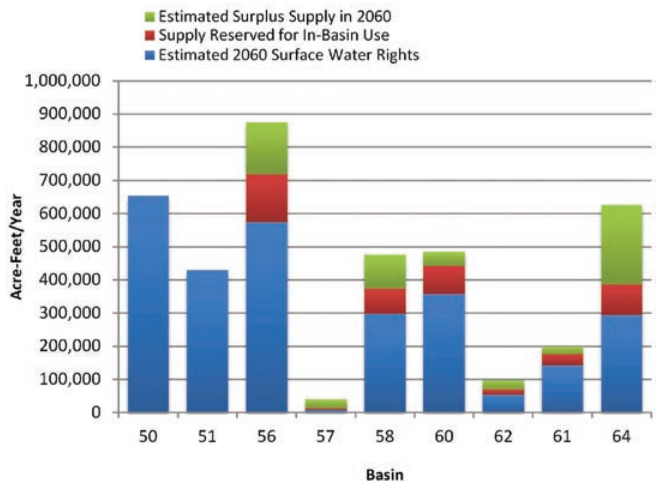


Estimated Surface Water Surplus in 2060

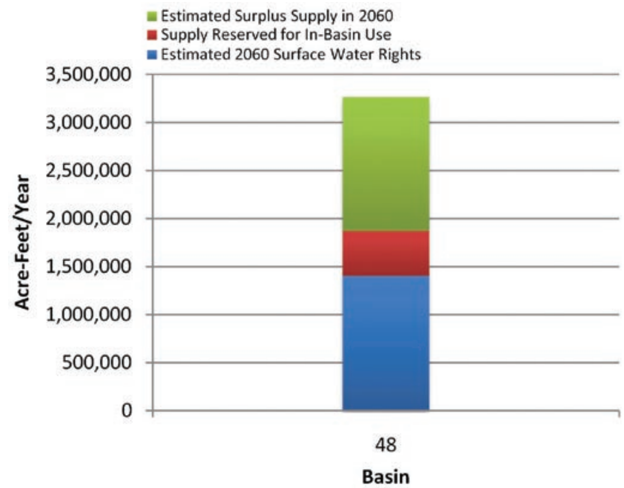
Blue-Boggy Region



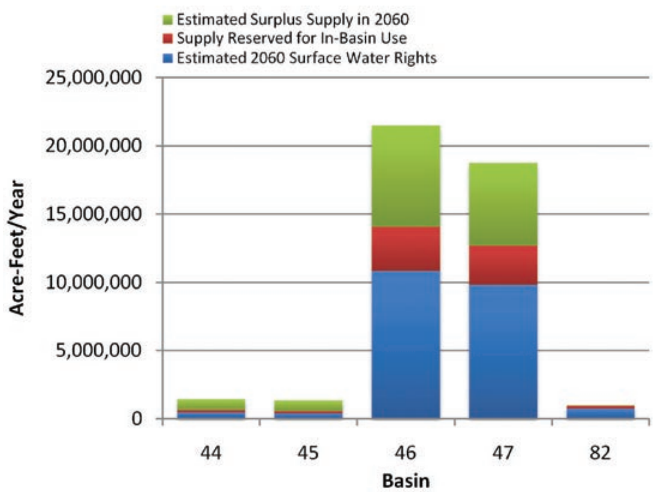
Estimated Surface Water Surplus in 2060
Central Region



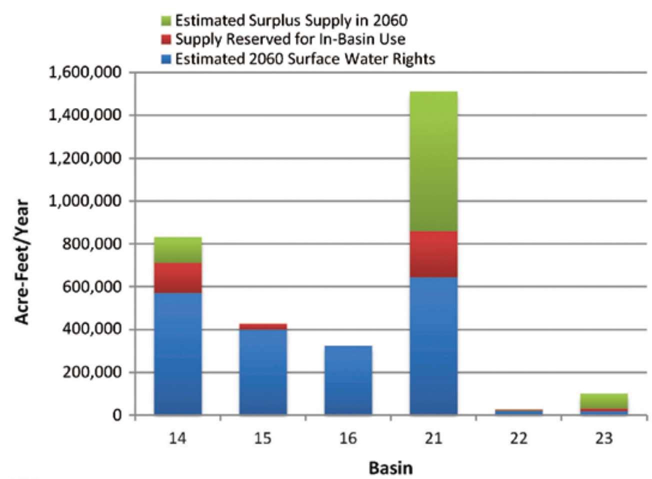
Estimated Surface Water Surplus in 2060
Eufaula Region



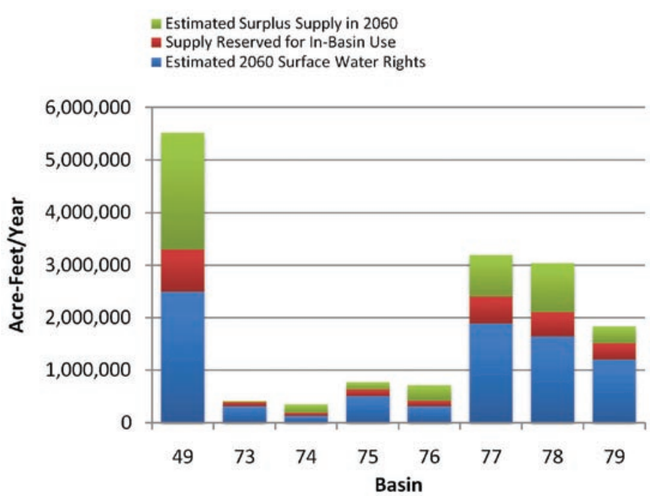
Estimated Surface Water Surplus in 2060
Lower Arkansas Region



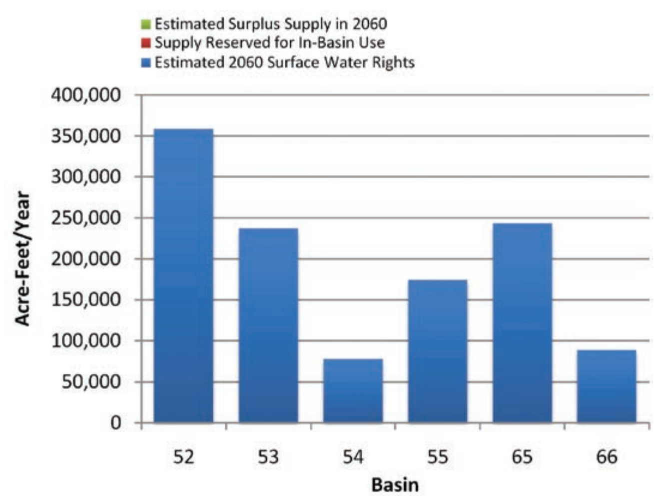
Estimated Surface Water Surplus in 2060
Lower Washita Region



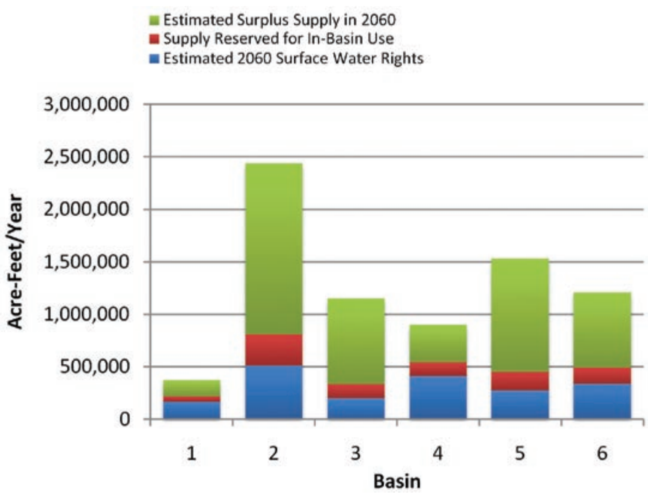
Estimated Surface Water Surplus in 2060
Middle Arkansas Region



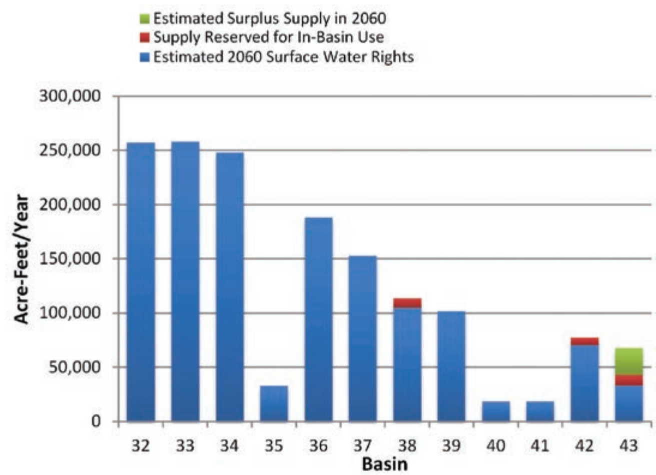
Estimated Surface Water Surplus in 2060
Panhandle Region



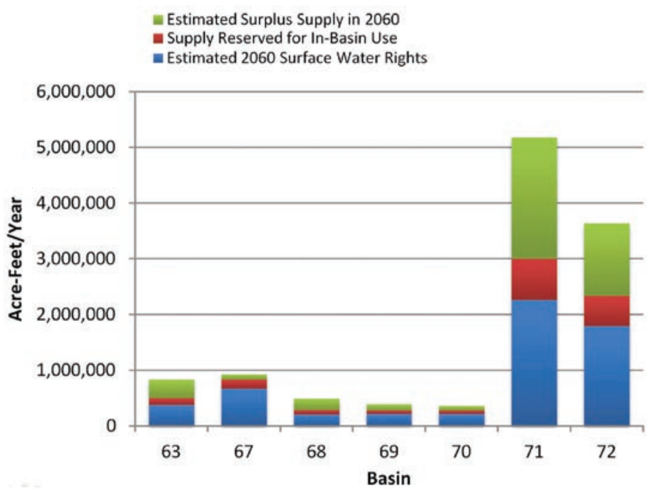
Estimated Surface Water Surplus in 2060
Southeast Region



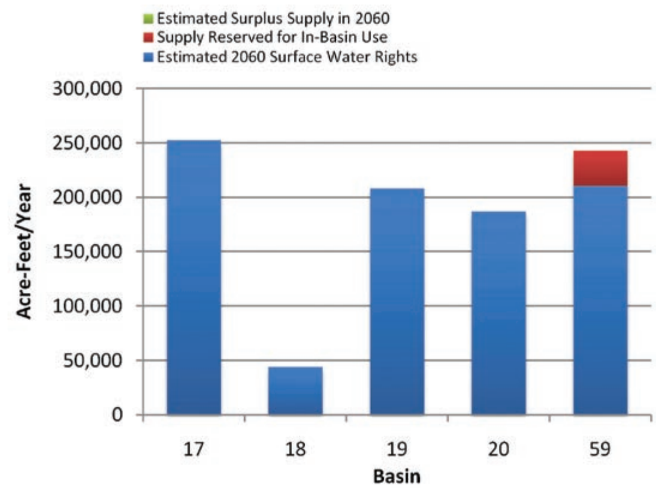
Estimated Surface Water Surplus in 2060
Southwest Region



Estimated Surface Water Surplus in 2060
Upper Arkansas Region



Estimated Surface Water Surplus in 2060
West Central Region



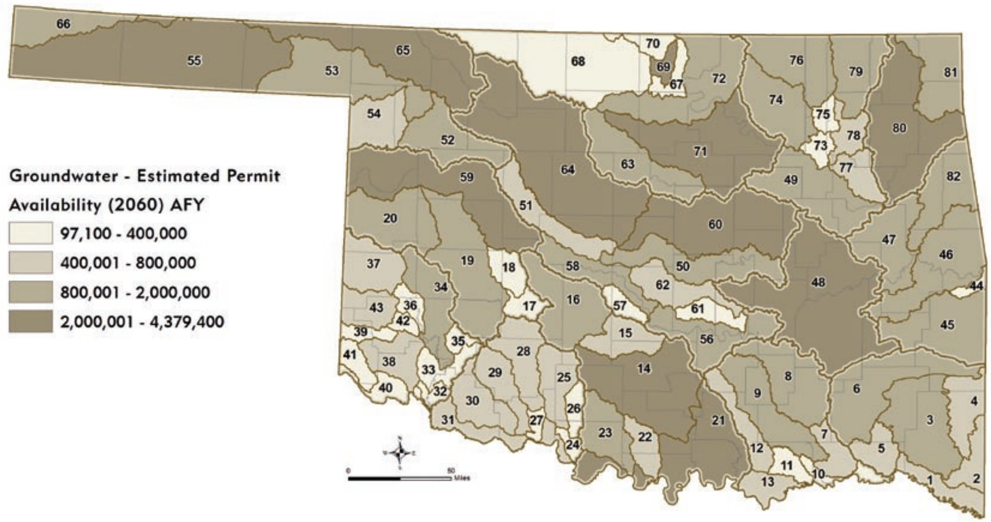
Groundwater Permit Availability

The permit availability of groundwater was determined for each of the 82 OCWP basins, including areas with and without studied groundwater basins. Two major types of groundwater permits are issued by the OWRB—regular and temporary. Regular groundwater permits are issued for aquifers that have been studied, a maximum annual yield (MAY) determined, and an equal proportionate share (EPS) approved. An EPS is the portion of maximum annual yield of groundwater in a given groundwater basin allocated to each acre of overlying land. Current EPS vary from 0.5 to 2.1 AFY per acre. In all areas with no defined EPS, a temporary permit of 2.0 AFY per acre may be issued.

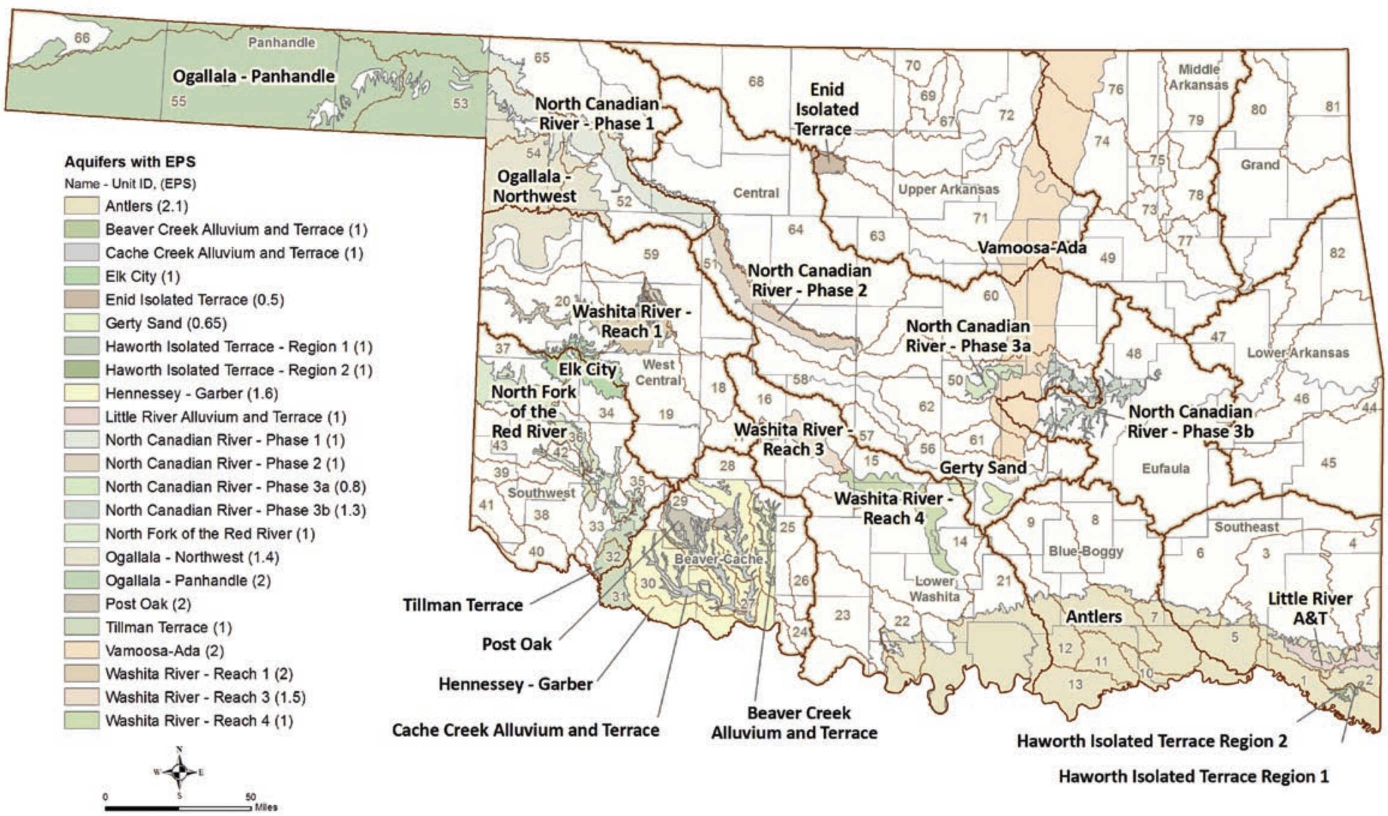
To calculate the maximum amount of groundwater available for permits, the geographical area of any underlying aquifers was determined for each basin. Since the OCWP basins were defined based on surface watersheds, Oklahoma's aquifers typically span multiple OCWP basins. For the groundwater permit availability analysis, the identified aquifers with EPS determinations had their respective EPS applied and for those basins without an EPS, 2 AF per surface acre (temporary) was applied. The total permit availability was determined by summing the EPS and temporary withdrawal volumes. Current (2007) permit availability was estimated by subtracting the existing active groundwater rights from the total permit availability. Since forfeiture of existing groundwater rights is rare, all existing active rights were used to conservatively represent the current portion of each basin that is not available for permits.

The quantity of groundwater that would need to be permitted by 2060 was estimated for each OCWP basin by summing the existing active groundwater rights and the increase in projected groundwater demand from 2007 to 2060. Demand increases were calculated using current (2007) surface water and groundwater supply proportions in each OCWP basin. A groundwater permit gap was estimated for the present (2010) and long-term (2060). The permit availability gap was calculated by subtracting the projected 2060 estimated groundwater permits from the total quantity that could be permitted in each OCWP basin. Since some existing rights are not entirely utilized, the projected 2060 groundwater permits resulting from this analysis may be greater than the projected future groundwater demand and thus provides a conservative forecast.

Estimated Available Groundwater for New Permits in 2060 by Basin



Current Equal Proportionate Share of Oklahoma Groundwater Basins



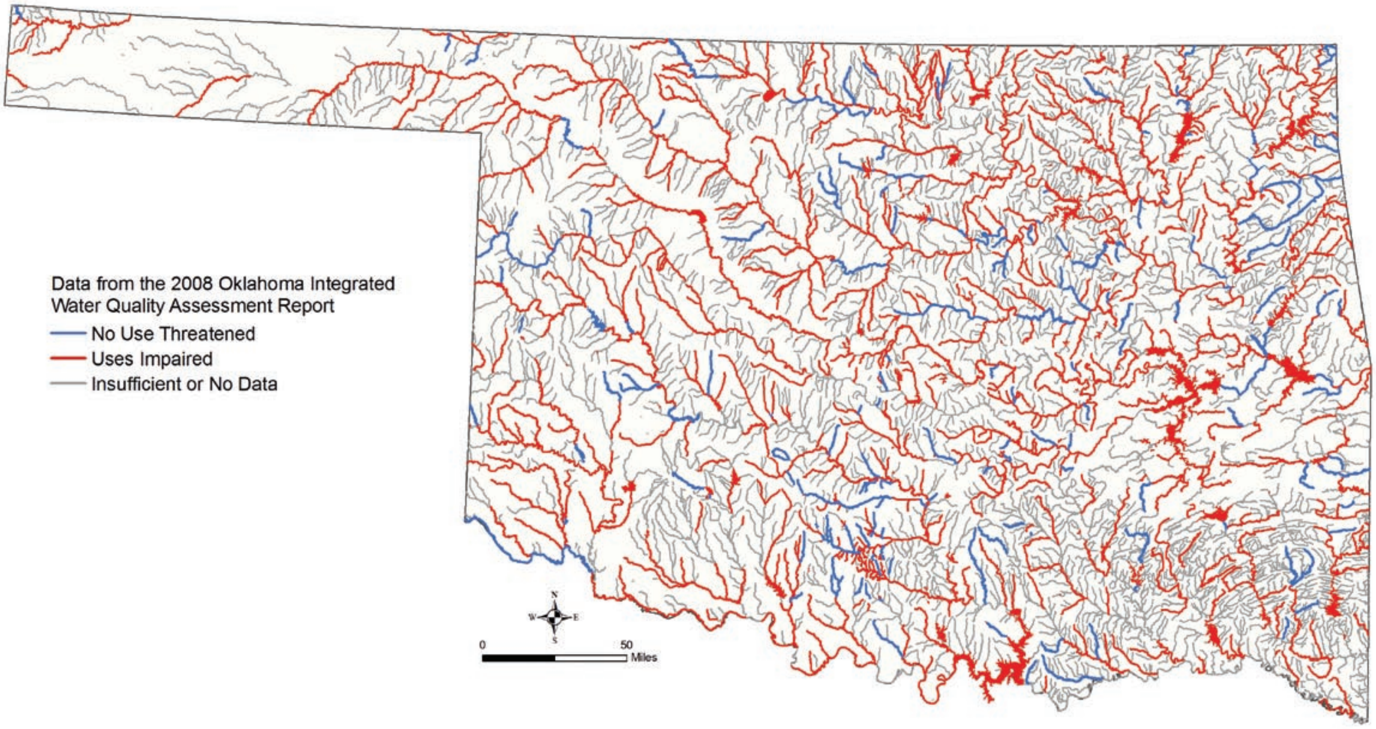
The groundwater permit availability analyses identified no near- or long-term groundwater permitting gaps in the state. Projected groundwater demand in 2060, assuming the continued use of current proportions of surface and groundwater in each basin, could be fully permitted under current law and permitting protocol. As additional aquifers are studied and updated, available groundwater for permits may increase or decrease relative to temporary or regular permit values.

Water Quality

Trends Analysis

Understanding the relative trends of various water quality constituents can significantly influence decisions related to the future availability, use, and allocation of water resources. Unfortunately, Oklahoma lacks a statewide groundwater quality monitoring program, and thus insufficient data exists to determine the impact of groundwater quality on water availability. However, the state does possess relatively adequate information on surface water quality. As part of the *2012 OCWP Update*, OWRB water quality monitoring staff compiled decades of water quality data from a variety of state

Statewide Surface Water Quality Assessment



and federal agencies and universities as well as OWRB's Beneficial Use Monitoring Program (BUMP) to initiate a continuing statewide analysis of surface water quality trends in Oklahoma.

For reservoirs, trends were analyzed for chlorophyll-a, conductivity, total nitrogen, total phosphorus, and turbidity at sixty-five reservoirs across the state. Data sets were of various lengths depending upon the station's period of record. The magnitude of trends varies throughout the state. Statewide, the final trend analysis revealed several notable details:

- Chlorophyll-a and nutrient concentrations continue to increase at a number of lakes. The proportions of lakes exhibiting a significant upward trend were 42% for chlorophyll-a, 45% for total nitrogen, and 12% for total phosphorus.
- Conductivity and turbidity have also trended upward. Nearly 28% of lakes show a significant upward trend in turbidity, while nearly 45% demonstrate a significant upward trend for conductivity.

Water quality trends for streams were analyzed for conductivity, total nitrogen, total phosphorus, and turbidity at sixty river stations across the state. Data sets were of various lengths depending upon the station's period of record, but data were generally divided into historical and recent datasets and analyzed separately and as a whole. Similar to reservoirs, the direction and magnitude of trends varies throughout the state. However, when considered statewide, the final streams trend analysis revealed several notable details.

- Total nitrogen and phosphorus are very different when comparing period of record to more recent data. When considering the entire period of record, approximately 80% of stream stations showed a downward trend in nutrients. However, if only the most recent data (approximately 10 years) are considered, the percentage of stations with a downward trend decreases to 13% for nitrogen and 30% for phosphorus. The drop is accounted for in stations with either significant upward trends or no detectable trend.
- General turbidity trends have also changed. During the entire period of record, approximately 60% of stations demonstrated a significant upward trend. More recently, that proportion has dropped to less than 10%.
- Conductivity trends have changed less dramatically. During the entire period of record, approximately 45% of stations demonstrated a significant upward trend. More recently, that proportion has dropped to less than 30%.

Statewide Assessment

Oklahoma works to protect and manage its water resources through a number of initiatives, with the Oklahoma Water Quality Standards (OWQS) serving as the cornerstone of the state's water quality management programs. The OWQS establish water quality benchmarks for the state's waterbodies, which lead to the development of permitting regulations and pollution control programs.

Oklahoma has well-established statewide surface water quality assessment programs. These programs culminate in development of several regularly released reports from state environmental agencies, federal partners, as well as some municipalities. Oklahoma's waters are evaluated concerning their ability to support Beneficial Uses which are prescribed in the OWQS (OAC 785:45).

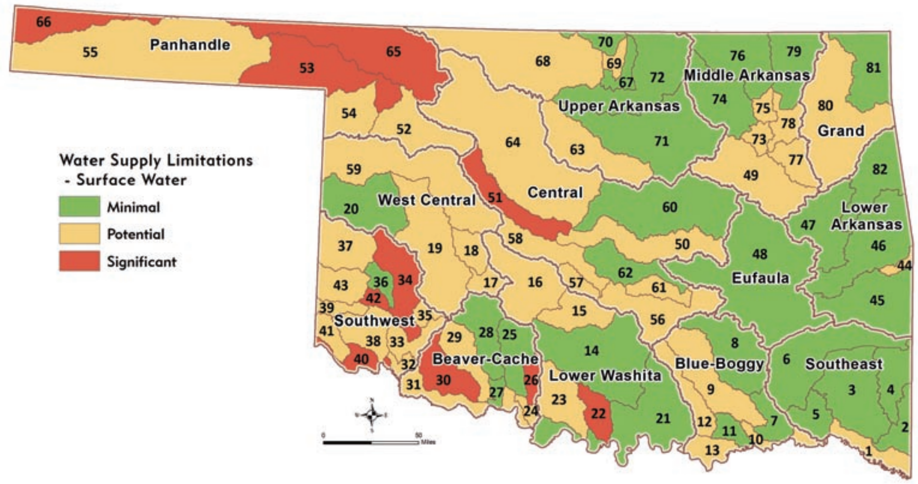
Every two years, through the leadership of the Oklahoma Department of Environmental Quality, the state of Oklahoma produces the *Oklahoma Integrated Water Quality Assessment Report* (*Integrated Report*). This report is a compilation of the monitoring and assessment activities of all of the state environmental agencies. This report gives a complete status of the state's waters as to how they compare to the federally approved OWQS. The data used to make these determinations must meet various quantity, quality, spatial, and temporal requirements in order to satisfy the attainment procedures. These data requirements, as well as detailed methodologies for assessing data, are found in Oklahoma's Use Support Assessment Protocols (USAP) housed in OAC 785:46. From the results of the Integrated Report, the Clean Water Act's Impaired Waters List, or "303(d) list", is compiled. This is a list of water bodies that do not meet water quality standards. The EPA is required to review the impaired waters list and approve or disapprove all or part of the list. The approved 303(d) list is then used to schedule and prioritize Total Maximum Daily Load (TMDL) development. The Integrated Report is intended to provide an effective tool for maintaining high quality waters and improving the quality of waters that do not attain water quality standards.

The Integrated Report also contains the 305(b) report which includes an analysis of the extent to which water bodies comply with the "fishable/swimmable" goal of the federal Clean Water Act. This analysis is considered to be a status and inventory of the water quality of all water bodies in the state.

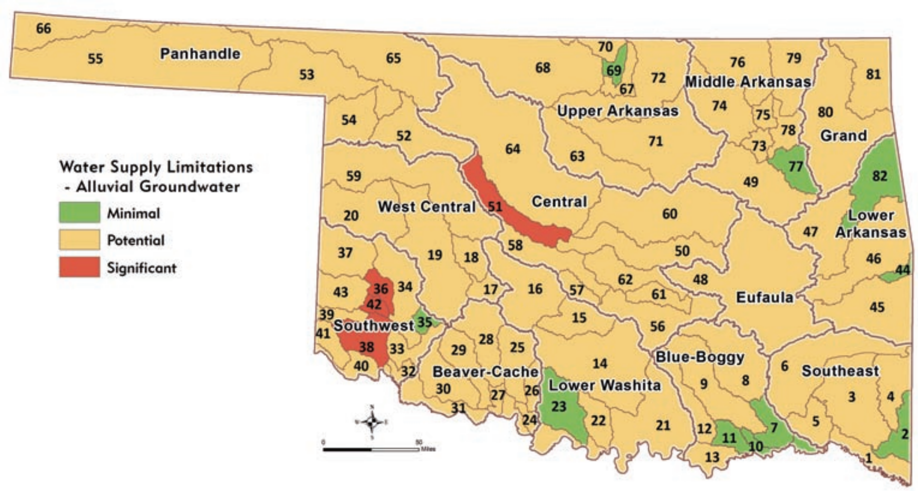
Water Supply Limitations Analysis

To develop appropriate options for addressing local water supply problems, the OCWP analysis of water supply and demand was ultimately followed by further analysis of potential limitations under baseline conditions for water use in each basin. For surface water, the most pertinent limiting characteristics considered

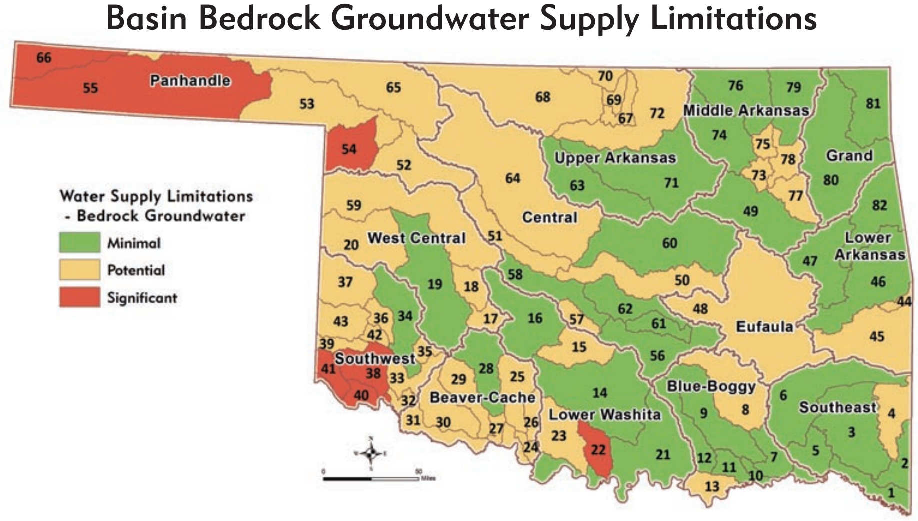
Basin Surface Water Limitations



Basin Alluvial Groundwater Supply Limitations



Basin Bedrock Groundwater Supply Limitations



were: (1) physical availability of water, (2) permit availability, and (3) water quality.

For alluvial and bedrock groundwater, studies determined that permit availability was not a limiting factor through 2060 and existing data was insufficient to conduct a similar analysis of groundwater quality limitations. Therefore, the most pertinent limiting characteristics included: (1) the amount of any forecasted depletion relative to the amount of water in storage, and (2) the rate at which the depletion was predicted to occur for major aquifers.

Methodologies were developed to assess limiting characteristics and assign appropriate scores to each basin. For surface water, scores were calculated weighting the characteristics: 50% for physical availability, 30% for permit availability, and 20% for water quality. For alluvial and bedrock groundwater scores, the magnitude of depletion relative to amount in storage and rate of depletion were each weighted 50%.

The resulting supply limitation scores were used to rank all 82 basins for each source. Basins ranking the highest for a particular source were considered to be significantly limited in the ability of that source to meet forecasted demands. Basins with intermediate rankings were considered to be potentially limited and those with the lowest rankings were considered to be minimally limited and not projected to have any gaps or depletions.

Basins with the most advanced limitations—the most severe water supply challenges—were identified as "Hot Spots." Methodologies used in identifying Hot Spots, results, and recommendations can be found in the "Regional/Statewide Opportunities & Solutions" section of this report.

Climate Change Implications on Supply and Demand

In recent years, significant national and international scientific studies have been initiated to understand and characterize the potential implications of climate variability including the impact on water resources. A wide range of models and assumptions are being employed by the scientific community to estimate future temperature, precipitation, and other factors affecting water supply and demand. The Oklahoma Climatological Survey, which has conducted a review and assessment of climate change research, concludes the following:

- The earth's climate has warmed during the last 100 years;
- The earth's climate will very likely continue to warm for the foreseeable future;
- Much of the global average temperature increases during the last 50 years can be attributed to human activities, particularly increasing greenhouse gases in the atmosphere; and
- Oklahoma will be impacted.

In particular, climate change is projected to continue to alter the water cycle across the U.S., including the total amount of annual precipitation and its location, timing, intensity, and probability. The U.S. Global Climate Research Program (USGCRP) projects that more frequent heavy rainfall events and droughts will affect much of the Great Plains as climate changes. The USGCRP notes, "Projections of increasing temperatures, faster evaporation rates, and more sustained droughts brought on by climate change will only add more stress to overtaxed water sources."

A variable precipitation history and an uncertain future under suspected climate change trends combine to challenge even the most forward-thinking and resourceful water resource managers, including critically vital water supply providers. While there remains significant uncertainty in the potential range of climate change and its impacts, particularly with regard to changes in precipitation, a sensitivity analysis of potential implications was undertaken through OCWP technical studies. By assessing the sensitivity of potential impacts on supply and demand from projected changes in climate, the OCWP provides unique insight into how the balance of water supply and water use might change if projections hold true.

Potential Effects on Temperature, Precipitation, and Water Supply

Review of current down-scaled climate projections for Oklahoma suggests that the southern Great Plains are likely to be warmer in the future, although the rate of warming will vary. Projections of precipitation differ from model to model and range between drier and wetter than historical conditions (USBR Technical Memorandum 86-68210-2010-01).

In order to assess the potential implication of surface water availability under climate change conditions, five climate change scenarios were developed consistent with available climate projection models. The models used and methodologies are discussed in greater detail in the OCWP *Water Demand Forecast Report* and *Conservation and Climate Change Addendum*.

The five scenarios were developed for two different projection horizons: 2030 and 2060. Four of the scenarios link to representative ensembles of projections along a range of potential temperature and precipitation conditions. At the extremes, Q1 is a hot and dry scenario and Q4 is a warm wet scenario. Q2 and Q3 are intermediate scenarios. The fifth scenario, "C," is the central tendency of Q1-Q4.

The OCWP methodology for developing climate projections closely followed that applied by the U.S. Bureau of Reclamation as part of their "ensemble hybrid-delta" method (USBR Technical Memorandum 86-68210-2010-01). Projections were developed by comparing differences in regional mean annual temperature and precipitation with the historical baseline.

the historical weather record with simulated runoff from an adjusted weather record that reflects projected changes in climate.

This work employed a physical process-based hydrology model—the Variable Infiltration Capacity (VIC) macro-scale hydrology model—that was run on a daily time step. Runoff was aggregated by stream basin and to a monthly time step. The estimated sensitivity of runoff to projected climate change was quantified by making two model runs: one that used the historical weather record (the baseline case) and a second, of identical length that used a projected weather record (the projected case). Each month in the projected record corresponds to the same month in the historical record. For each month in the historical record, the sensitivity of runoff to climate change is expressed as the ratio between the runoff simulated using the projected record and the runoff simulated using the historical record.

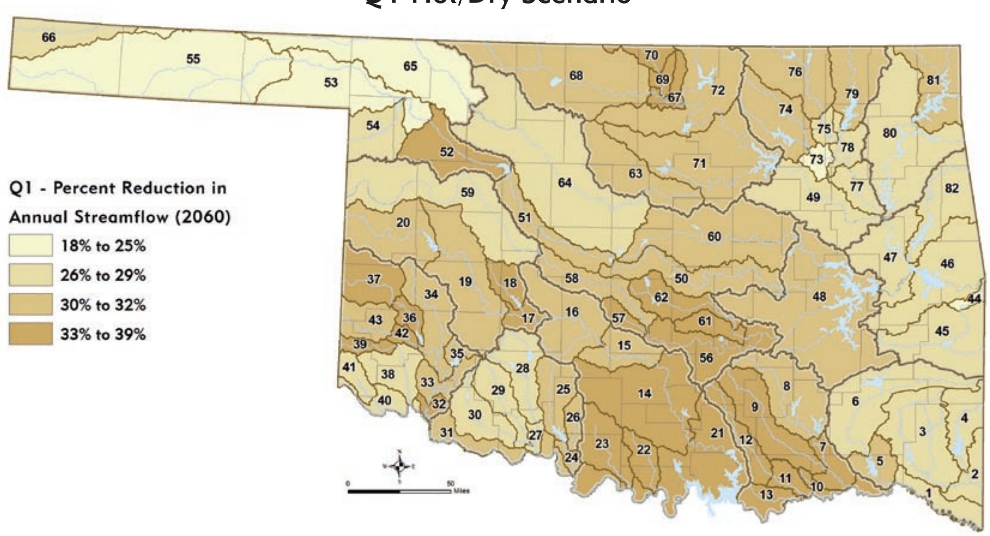
For each of the five scenarios and each month, climate adjustment factor distributions were calculated utilizing the differences between the ensemble pools of data and the historical baseline data set. These adjustment factors were then applied to the historical time series data set to incorporate climate change impacts associated with the given planning horizon while maintaining historical patterns of month-to-month variability.

To bracket the range of potential climate projections and in light of the uncertainties in climate change projections, two scenarios—Q1 (Hot/Dry) and Q4 (Warm/Wet)—were selected for estimating potential future conditions in Oklahoma. The impact on temperature and precipitation under those scenarios was used to estimate the potential implications on both surface water supply and demand throughout the state.

A hydrology model was used to quantify the sensitivity of runoff to changed climate conditions. This sensitivity was expressed as a set of changes in runoff that were estimated by comparing simulated runoff based upon

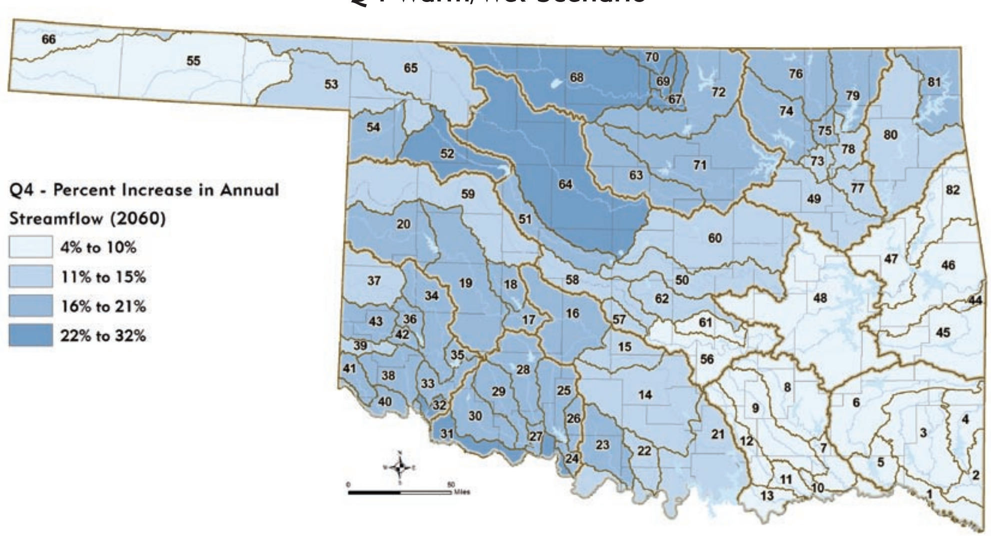
Potential Change in Annual Streamflow in 2060

Q1 Hot/Dry Scenario



Potential Change in Annual Streamflow in 2060

Q4 Warm/Wet Scenario



Statewide M&I Demand Forecast Under Climate Change Scenarios

Year	Baseline (AFY or %)	Hot/Dry (AFY or %)	Warm/Wet (AFY or %)
2030	682,391	718,747	699,119
2060	772,773	846,029	805,398
Change from Baseline			
2030	N/A	36,356	16,727
2060	N/A	73,256	32,625
Percent Increase from Baseline			
2030	N/A	5.3%	2.5%
2060	N/A	9.5%	4.2%

Statewide Crop Irrigation Demand Forecast Under Climate Change Scenarios

Year	Baseline (AFY or %)	Hot/Dry (AFY or %)	Warm/Wet (AFY or %)
2030	806,112	892,221	823,622
2060	897,464	1,041,032	926,557
Change from Baseline			
2030	N/A	86,109	17,511
2060	N/A	143,567	29,093
Percent Increase from Baseline			
2030	N/A	10.7%	2.2%
2060	N/A	16.0%	3.2%

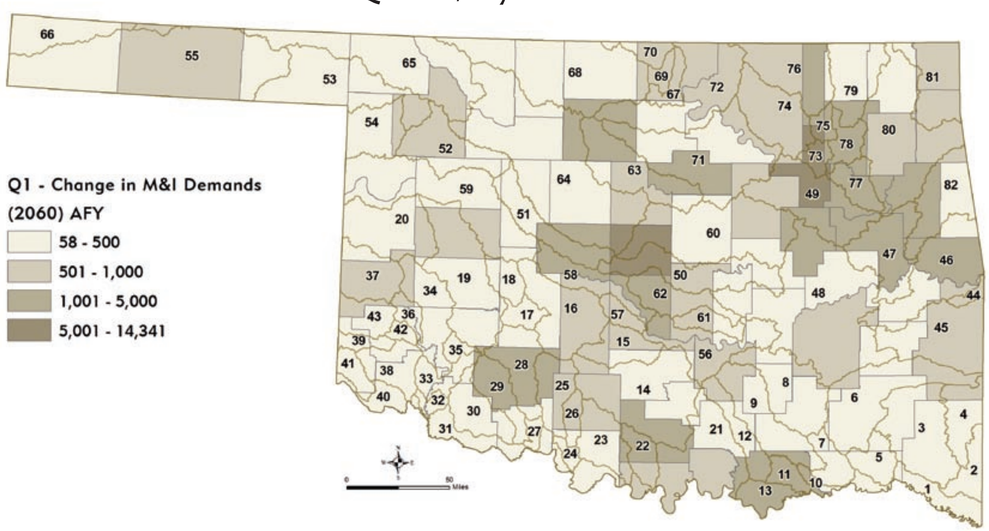
The projected effects in 2060 on surface water flows are expressed as a change relative to the 1950-2007 historical average for each scenario, thus demonstrating the range of impacts to surface water supplies. Additional information and projections for the 2030 time frame and other scenarios are provided, along with detailed explanations of the models, in the OCWP *Climate Impacts to Streamflow* report.

Potential Effects on Water Demand

Recognizing that changes in our climate would affect both Oklahoma's water supplies and demand, the OCWP technical analyses also considered the potential for climate change to affect certain demand sectors' forecasted water use. Specifically, the M&I and crop irrigation demand sectors were analyzed for how they could change under the Hot/Dry (Q1) and Warm/Wet (Q4) climate change scenarios previously described. These two demand sectors were analyzed because they both include outdoor irrigation that has the potential to be significantly affected by climate change. The state's other five demand sectors may be affected to some degree by climate change, but those impacts would be expected to be less significant than the M&I and Crop Irrigation demand sectors. Moreover, these two

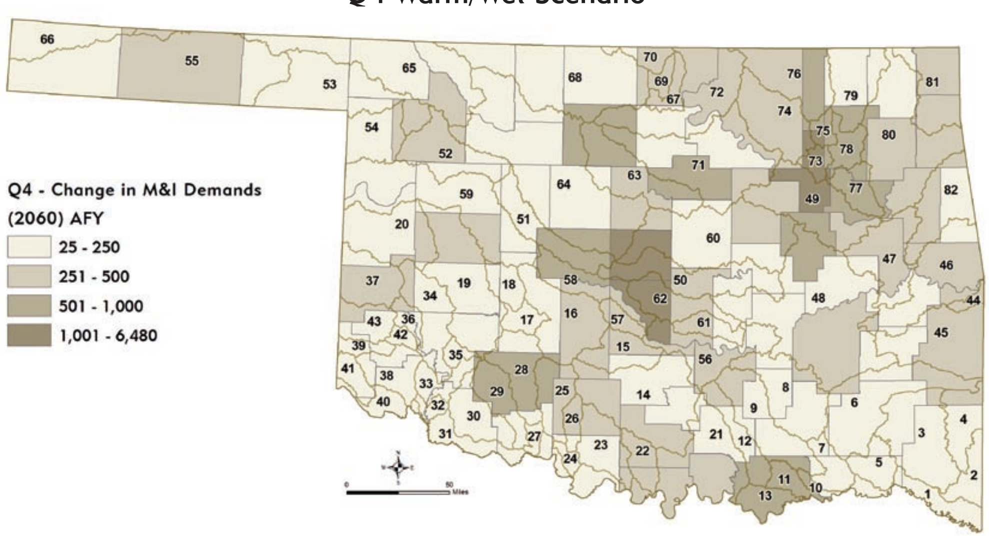
Potential Change in Municipal/Industrial Demand With Climate Change

Q1 Hot/Dry Scenario



Potential Change in Municipal/Industrial Demand With Climate Change

Q4 Warm/Wet Scenario



demand sectors together comprise more than two-thirds of Oklahoma's water demand and are major drivers for water use in the state.

M&I Demand

Statistical results of the OCWP Climate Demand Model were used to model the impacts of climate change on M&I water demand. The Climate Demand Model was developed using regression analysis and assessed the relationship between weather and monthly water demand for five communities in geographically diverse areas of Oklahoma. Details of the Climate Demand Model are documented in the OCWP Weather Production Model Revised Final Technical Memorandum (CDM, 2010). The relationships between M&I demand and historical weather are expressed as elasticities, or the percent change in monthly water demand given a unit change in monthly weather.

Variation in both monthly average daily maximum temperature and monthly total precipitation were found to have statistically significant relationships with water production. The elasticities for maximum temperature and precipitation were used to adjust monthly water demand estimates for the potential shifts in maximum temperature and precipitation.

The projected 73,256 AFY increase in 2060 demand under the Hot/Dry scenario is significant, equivalent to the projected increase in demand under the baseline (no climate change) scenario of approximately 20 years of M&I demand growth in Oklahoma.

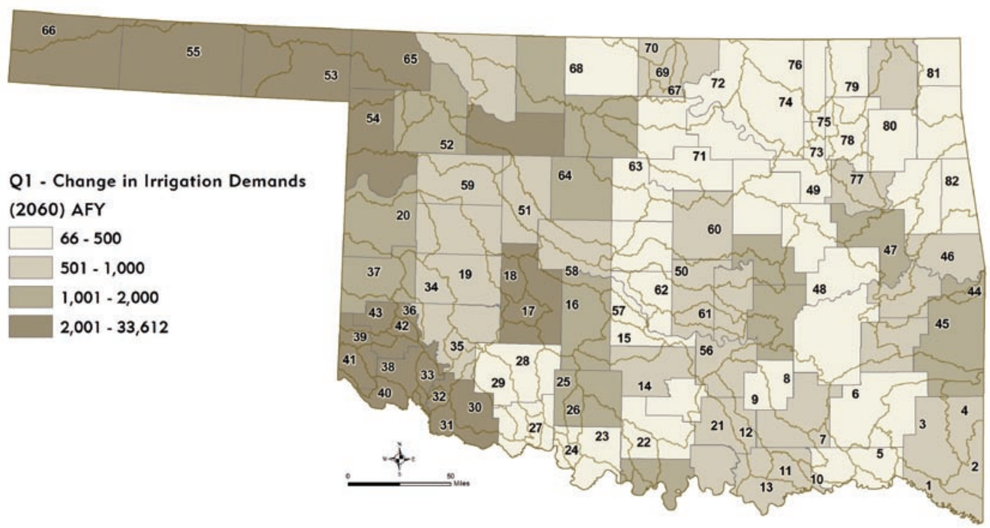
Crop Irrigation Demand

Modeling climate change impacts on crop irrigation demand required adaptation and use of the OCWP Water Demand Model developed for the OCWP baseline forecast. The model considers a county's number of acres to be irrigated in the future, relative crop mix, monthly irrigation requirements for each crop, and losses due to irrigation system inefficiencies. The baseline forecast used monthly irrigation requirements for crops at 11 stations throughout Oklahoma, as reported in the *NRCS Irrigation Guide Report, Oklahoma Supplement* (Natural Resource Conservation Service, 2006).

For the climate change scenario forecast, it was assumed that the number of irrigated acres, relative mix of crops, and irrigation efficiencies would remain constant from the baseline forecast. Irrigation crop requirements by station were assumed to change given climate change scenarios. Changes to the baseline forecast for county crop irrigation demand were calculated using NRCS methods and the Q1/Q4 climate inputs. Those changes were then applied to the baseline demand to project crop irrigation demand under climate change conditions.

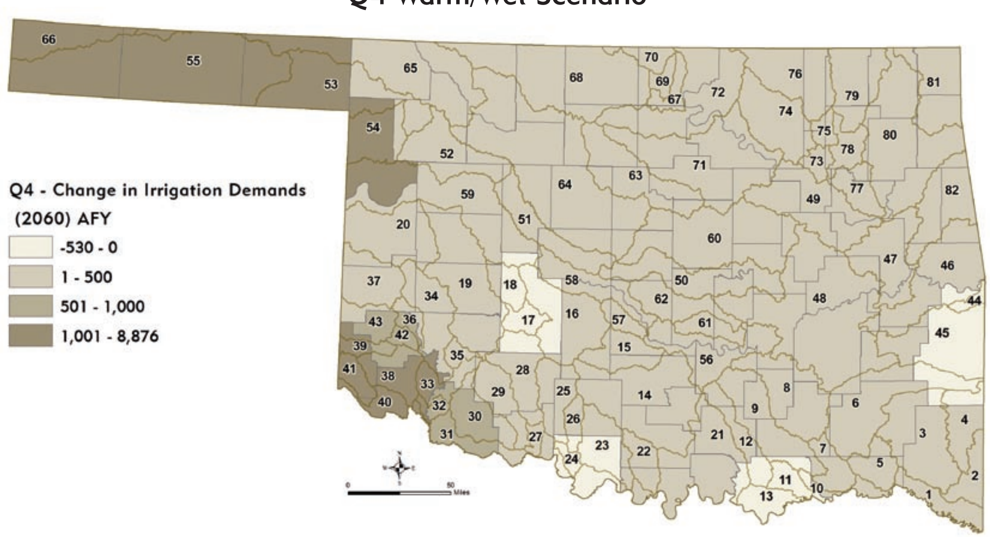
Potential Change in Crop Irrigation Demand With Climate Change

Q1 Hot/Dry Scenario



Potential Change in Crop Irrigation Demand With Climate Change

Q4 Warm/Wet Scenario



The projected 143,567 AFY increase in 2060 crop irrigation demand under the Q1 hot/dry scenario is significant, equivalent to the projected increase in demand under the baseline (no climate change) scenario of approximately 50 years of statewide crop irrigation demand growth.

Implications for Water Supply Shortages

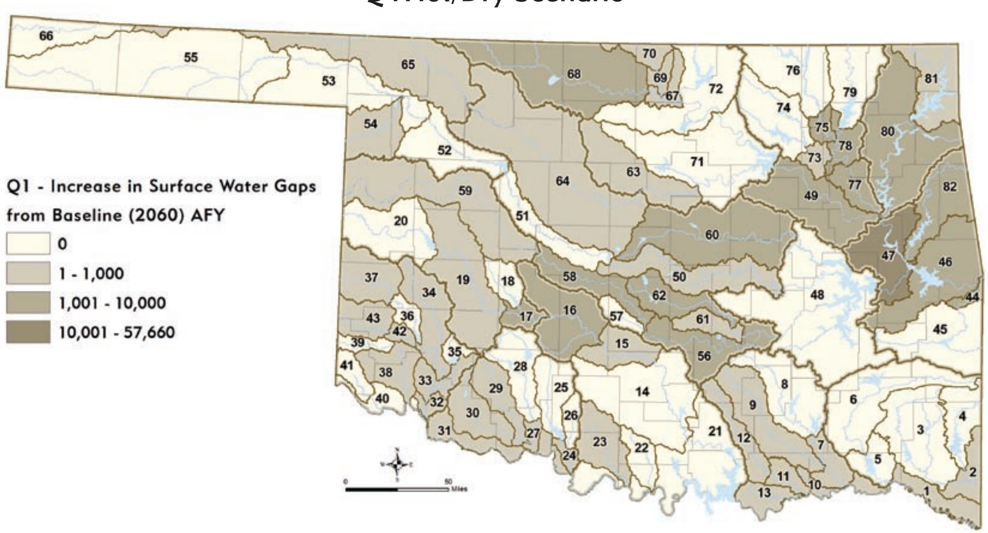
Ultimately, the effects of climate change on Oklahoma's surface water supplies and water demand could affect the shortages users will face in the future. To characterize those possible implications, projections of monthly surface water flow for each of the 82 OCWP basins under climate change were input into the Oklahoma H2O tool, along with projections of demand under climate change conditions. The M&I and Crop Irrigation county-level demand projections the Q1 and Q2 climate change scenarios were allocated to the 82 OCWP basins using the same methods employed for allocating baseline county demand values to baseline basin-level demand forecasts.

Other than the climate change-driven adjustments to surface water supply (streamflow data), crop irrigation demand, and M&I demand, no other modifications were made relative to the baseline scenario for projecting future water shortages under climate change. Specifically, the changes in the surface water gaps in each basin were examined for 2030 and 2060 conditions under the Hot/Dry and Warm/Wet scenarios.

Impacts on surface water gaps are expected to be most significant under the Hot/Dry scenario and are anticipated to increase in severity. Federal, state, and local water planners should continue to monitor climate change science in light of these potential impacts on Oklahoma's supplies and demand.

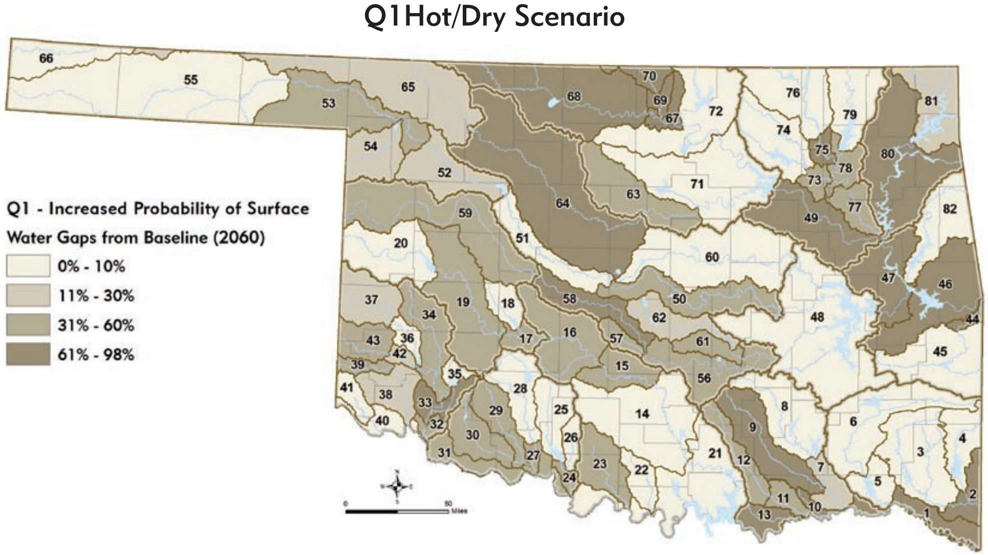
Increase in 2060 Surface Water Gap Magnitudes

Q1Hot/Dry Scenario



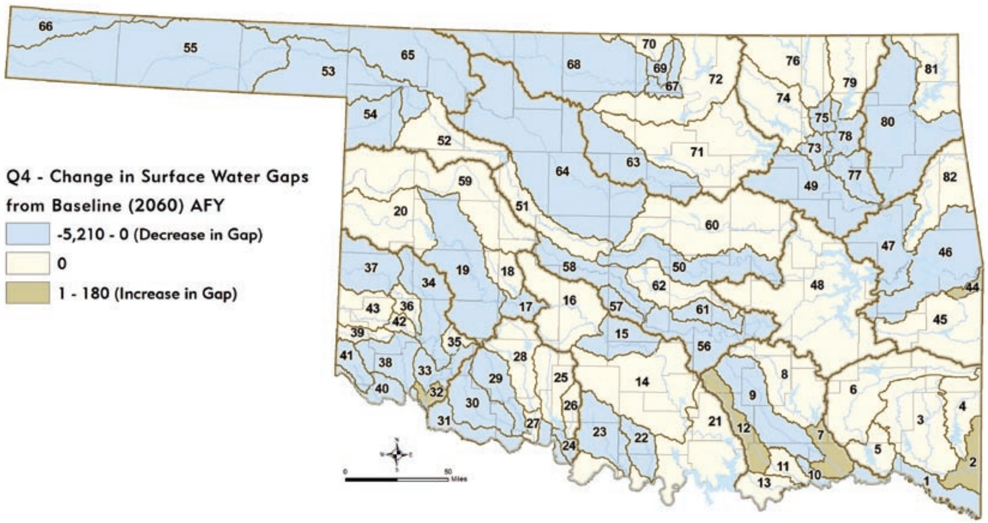
Increase in Probability of 2060 Maximum Surface Water Gaps

Q1Hot/Dry Scenario



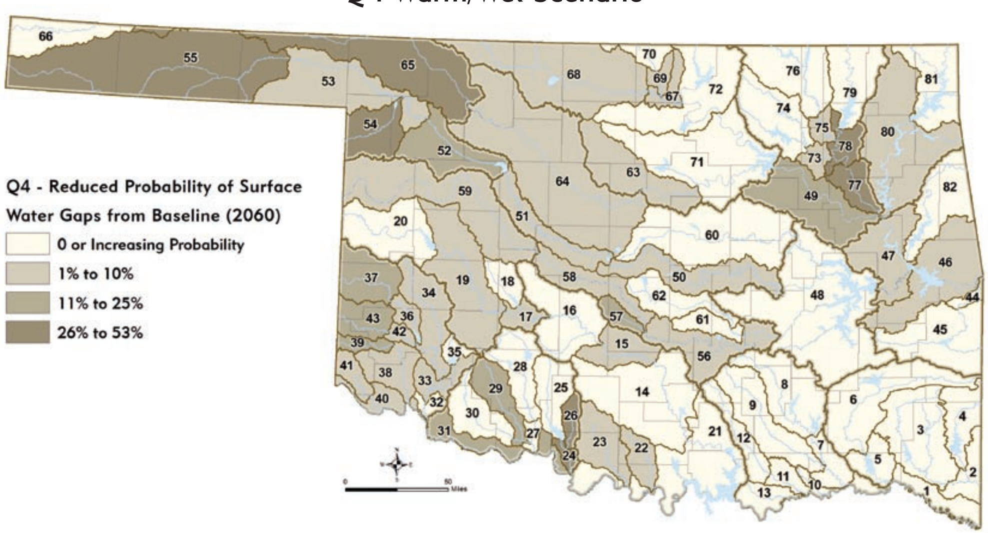
Change in 2060 Surface Water Gap Magnitudes

Q4 Warm/Wet Scenario



Reduction in Probability of 2060 Maximum Surface Water Gaps

Q4 Warm/Wet Scenario



Regional/Statewide Opportunities & Solutions

Water Supply Options

Several components of the *2012 OCWP Update* focus on water supply options for reducing and eliminating future water supply shortages. An OCWP analysis of water supply and demand was completed for each of the state's 82 OCWP basins and summarized in the 13 Watershed Planning Region reports. Basins projected to have surface water gaps or groundwater depletions were identified by decade through 2060, and five primary potential options were evaluated for effectiveness in addressing each basin's shortages: (1) demand management, (2) use of out-of-basin supplies, (3) reservoir use, (4) increasing reliance on surface water, and (5) increasing reliance on groundwater. In four separate statewide studies, expanded options for reducing or eliminating future water supply shortages were analyzed; these studies focused on (1) expanded conservation measures, (2) potential reservoir development, (3) marginal quality water use, and (4) artificial recharge projects. In response to public interest, the "Statewide Water Conveyance System" study, which updated conveyance costs from the *1980 OCWP*, was also compiled. Full reports on all OCWP water supply options can be viewed on the OWRB website.

Primary Options

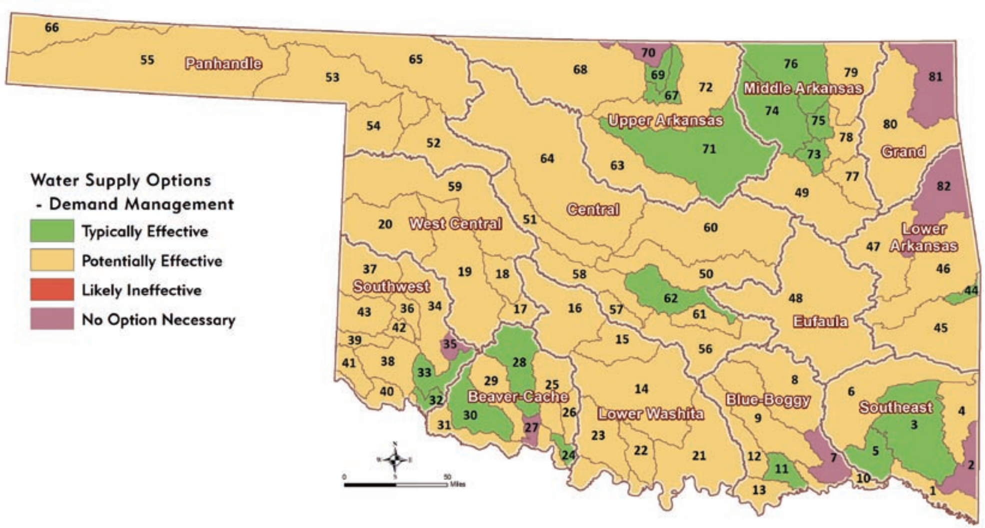
To provide a range of potential solutions for mitigation of water supply shortages in each basin, five primary options were evaluated and are summarized below. For each basin in which shortages were projected, the potential effectiveness of each primary option was assigned one of three ratings: (1) typically effective, (2) potentially effective, and (3) likely ineffective. For basins where shortages are not projected, no options are necessary and thus none were evaluated.

Demand Management

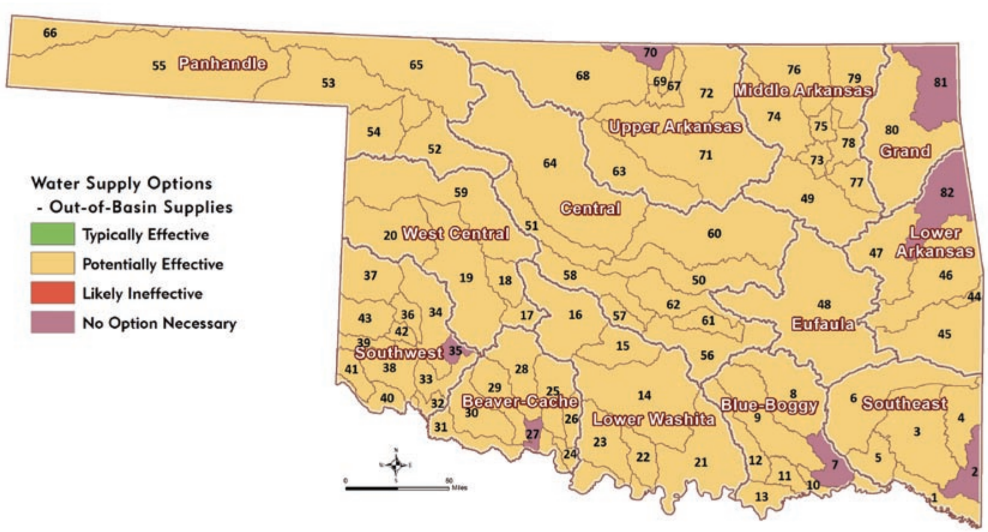
"Demand management" refers to the potential to reduce water demands and alleviate gaps or depletions by implementing conservation or drought management measures. Demand management is a vitally important tool that can be implemented to either temporarily or permanently decrease demand and increase available supply. "Conservation measures" refer to long-term activities that result in consistent water savings throughout the year, while "drought management" refers to short-term measures, such as temporary restrictions on outdoor watering. Municipal and industrial conservation techniques can include modifying customer behaviors, using more efficient plumbing fixtures, or eliminating water leaks. Agricultural conservation techniques can include reducing water demand through more efficient irrigation systems and production of crops with decreased water requirements.

The OCWP analyzed two specific scenarios for conservation—moderate and substantial—to assess the relative effectiveness in reducing statewide water demand in the Municipal and Industrial and Crop Irrigation

Basin Water Supply Options, Demand Management



Basin Water Supply Options, Out-of-Basin Supplies



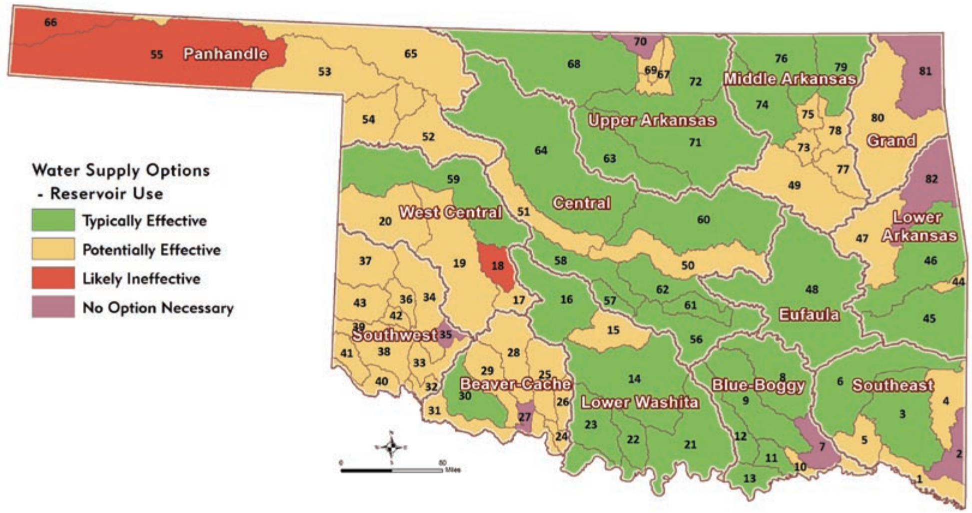
sectors. For the Watershed Planning Region reports, only moderately expanded conservation activities were considered when assessing the effectiveness of the demand management option in a basin. An analysis of moderate and substantial conservation measures is summarized in the following “Expanded Options” section.

Demand management was considered to be “typically effective” in basins where it would likely eliminate both gaps and storage depletions and “potentially effective” in basins where it would likely either reduce gaps and depletions or eliminate either gaps or depletions (but not both). There were no basins where demand management could not reduce gaps and/or storage depletions to at least some extent; therefore this option was not rated “likely ineffective” for any basin.

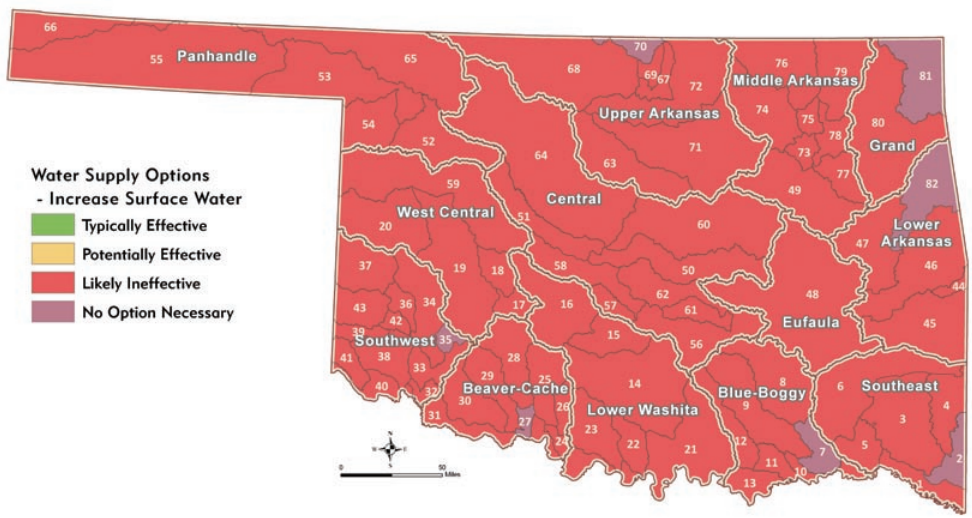
Out-of-Basin Supplies

“Out-of-basin supplies” refers to the option of transferring water through pipelines from a source of supply in one basin to another basin. Due to general potential in eliminating gaps and depletions, use of out-of-basin supplies is considered a potentially effective solution in all planning basins, but because of the potential complexity and cost, development of out-of-basin supplies is normally only considered as a long-term solution. The effectiveness of this option for a basin was also assessed with the consideration of potential new reservoir sites within the respective region as identified in the OCWP *Reservoir Viability Study* report.

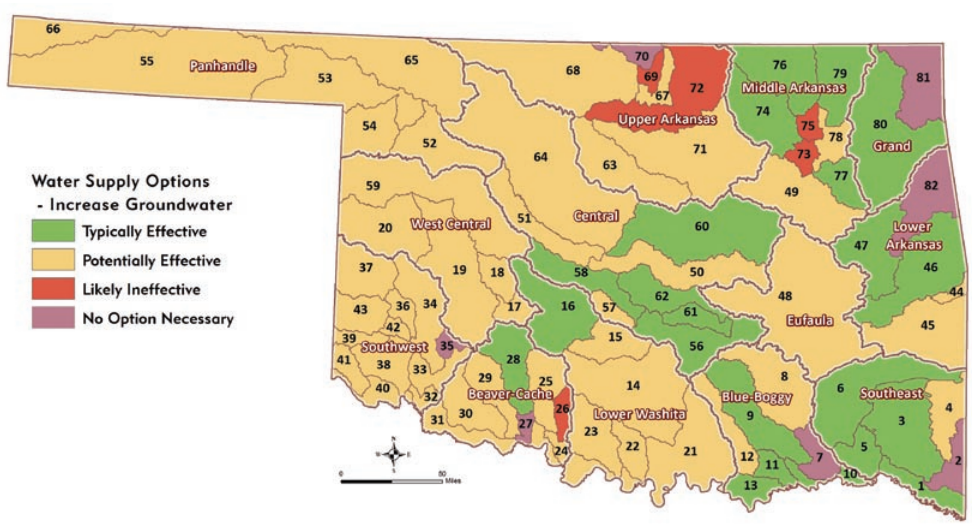
Basin Water Supply Options, Reservoir Use



Basin Water Supply Options, Increasing Reliance on Surface Water



Basin Water Supply Options, Increasing Reliance on Groundwater



Reservoir Use

"Reservoir use" refers to the development of additional in-basin reservoir storage. Reservoir storage can be provided through increased use of existing facilities, such as reallocation of existing purposes at major federal reservoir sites or rehabilitation of smaller NRCS projects to include municipal and/or industrial water supply, or the construction of new reservoirs.

The effectiveness of reservoir use for a basin depends on available streamflow. Discussion of this option is based on a hypothetical reservoir located at the furthest downstream basin outlet. Water transmission and legal or water quality constraints were not considered. A site located elsewhere in the basin could potentially provide adequate yield to meet demand, but would likely require greater storage than a site located at the basin outlet.

Recognized in the analysis of this option are potentially viable new reservoir sites identified in the Expanded Options section and OCWP *Reservoir Viability Study*. Reservoir use was considered typically effective in basins containing one or more potentially viable proposed reservoir sites unless the basin was fully allocated for surface water and had no permit availability. For basins with no permit availability, reservoir use was considered potentially effective since diversions would be limited to existing permits. Reservoir use was also considered potentially effective in basins that did not possess an identified viable reservoir site but would generate sufficient streamflow and reservoir yield to meet future demand. Statewide, the option is considered likely ineffective in only three basins (Basins 18, 55, and 66), where it was determined that insufficient streamflow will be available to provide an adequate reservoir yield to meet basin demand.

Increasing Reliance on Surface Water

"Increasing reliance on surface water" refers to changing the surface water-groundwater use ratio to meet future demands by increasing surface water use. For the baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector was assumed to be equal to current proportions. Increasing the use of surface water through direct diversions, without reservoir storage or releases upstream from storage, may provide a reliable supply option in limited areas of the state and has potential to mitigate bedrock groundwater depletions and/or alluvial groundwater depletions. However, this largely depends upon local conditions and the specific location, amount, and timing of the diversion. Due to this uncertainty, the pronounced periods of low streamflow in many river systems across the state, and the potential to create or increase surface water gaps, this option is considered typically ineffective. In any case, careful analysis would be required. The preferred alternative statewide is reservoir use, which provides the most reliable supply source.

In general, increasing reliance on surface water supply through direct diversions, without the advantage of storage or upstream releases from storage, was considered typically ineffective in all basins for which the analysis was performed. Increasing reliance on surface water may be potentially effective in basins without gaps and storage depletions; however, no analyses were performed for these basins.

Increasing Reliance on Groundwater

"Increasing reliance on groundwater" refers to changing the surface water-groundwater use ratio to meet future demands by increasing groundwater use. Increasing use of either alluvial or bedrock aquifers could provide additional future supplies and help reduce or eliminate gaps and/or depletions. Assessment of this option was based on an analysis of the impact of increased groundwater use on basin-wide gaps and depletions but was not geographically specific within each basin. Supplies from major aquifers are particularly reliable because they generally exhibit higher well yields and contain large amounts of water in storage. Site-specific information on the suitability of minor aquifers for supply should be considered prior to large scale use. Additional groundwater supplies may also be developed through artificial recharge (groundwater storage and recovery), which is summarized in the Expanded Options section.

Increased reliance on groundwater supplies was considered typically effective in basins where both gaps and depletions could be mitigated in a measured fashion that does not actually lead to groundwater depletions. This option was considered potentially effective in basins where surface water gaps could be mitigated but would result in increased depletions in either alluvial or bedrock groundwater storage. Increased reliance on groundwater supplies was considered typically ineffective in basins where there were no major aquifers.

Expanded Options

In addition to the standard analysis of primary options for each basin, specific OCWP studies were expanded to thoroughly explore several options that have potential to reduce basin gaps and depletions: (1) expanded conservation measures, (2) potential reservoir development, (3) marginal quality water use, (4) artificial recharge projects, and (5) statewide water conveyance. These options, summarized in the following section, are documented respectively in the following OCWP reports: *Conservation and Climate Change Addendum*, *Reservoir Viability Study*, *Marginal Quality Water Issues and Recommendations*, *Artificial Aquifer Recharge Issues and Recommendations*, and *Water Conveyance Study*.

Expanded Conservation Measures

Water conservation was considered an essential component of the "demand management" option in basin-level analysis of options for reducing or eliminating gaps and storage depletions. At the basin level, moderately expanded conservation measures were used as the basis for analyzing effectiveness. In a broader OCWP study, documented in the report *Conservation and Climate Change Addendum*, both moderately and substantially expanded conservation activities were analyzed at a statewide and county level for the state's two largest demand sectors: Municipal and Industrial (M&I) and Crop Irrigation. For each sector, two scenarios were analyzed: Scenario I– moderately expanded conservation activities, and Scenario II–substantially expanded conservation activities.

Summary of OCWP Conservation Scenarios

Demand Sector	Conservation Scenario	Description
Municipal & Industrial*	Scenario I: Moderately Expanded Conservation	• Passive conservation achieved by 2060 for Public-supplied Residential Sector and by 2030 for Public-Supplied Nonresidential Sector. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • At least 90% of water providers in each county will meter their customers. • Non-revenue water loss will be reduced to 12%, where applicable. • Conservation pricing will be implemented by 20% of water providers in rural counties, 40% in mostly urban counties, and 60% in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers (including billing inserts and conservation tip websites) which is estimated to reduce demands by 3%.
	Scenario II: Substantially Expanded Conservation	• Passive conservation (as described in Scenario I). • All water providers will meter their customers. • Non-revenue water loss will be reduced to 10% where applicable. • Conservation pricing will be implemented by 60% of providers in rural counties, 80% in mostly urban counties, and 100% in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5% including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I: Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80% beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42). • In Harmon, Jackson, Tillman, and Kiowa counties, 10% of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42). • All sprinkler systems will have a field application efficiency of 90% beginning in 2015, representing implementation of low energy precision application (LEPA) nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II: Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • Shift all acres of water-intensive crops (corn for grain and forage crops, including alfalfa and pasture grass) to less water-intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water-intensive crop production will stop, this assumption allows for analysis of full implementation of the "what if" scenario.

**also includes self-supplied residential demand where appropriate.*

An important tool in managing water resources, water conservation can be implemented on both the demand and supply/distribution sides of water management. M&I demand side conservation techniques reduce water demand by changing consumer behavior through implementing education programs, promoting the use of water efficient appliances, and employing conservation pricing. Supply or distribution conservation involves effective management of system water losses through metering, analysis of water use, and leak detection. Reduced water demand from conservation prolongs the lifespan of current supplies, allowing utilities to defer, downsize, or even eliminate costly investment in new facilities and water supplies. Customers benefit from conservation through reduced water and energy utility bills.

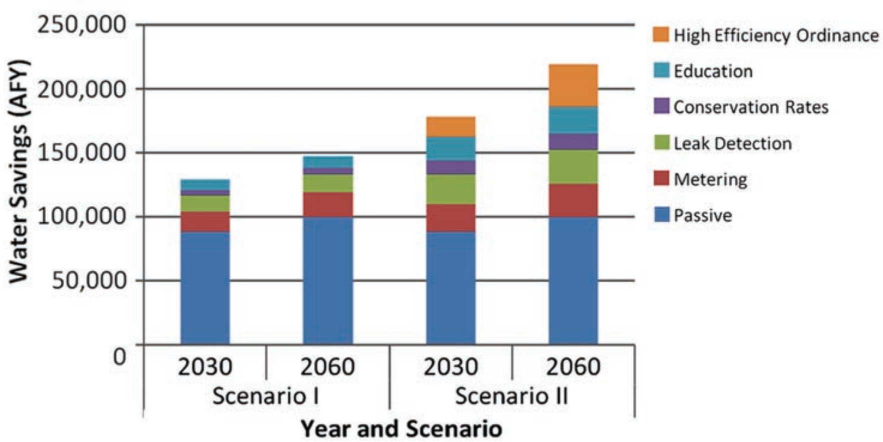
Agricultural supply side conservation reduces water demand through activities such as implementation of irrigation systems with increased efficiencies and production of crops with decreased water requirements.

Water savings for the M&I and Crop Irrigation demand sectors were assessed, and for the M&I sector, a cost-benefit analysis was performed to quantify savings associated with reduced costs in drinking water production and decreased wastewater treatment. The energy savings and associated water savings realized as a result of these decreases were also quantified.

M&I Water Conservation Measures

Scenario I (moderately expanded conservation measures) for the M&I sector included "passive conservation"

Estimated Statewide M&I Water Savings by Program and Scenario



Statewide Demand Projections and Water Savings for M&I Conservation Scenarios

	2020	2030	2040	2050	2060
	AFY				
Baseline	679,648	717,161	750,844	782,137	813,928
Scenario I	585,746	588,269	615,650	641,026	666,806
Scenario II	547,251	538,908	554,837	571,788	594,646
Change from Baseline (AFY)					
Scenario I	93,902	128,891	135,194	141,111	147,122
Scenario II	132,397	178,253	196,007	210,348	219,283

Statewide Water Savings from Reduced Water Production/Wastewater Treatment in 2060

(2010 dollars)

	Surface Water	Groundwater	Wastewater	Total
Scenario I	$26,036,731	$2,903,100	$18,510,151	$47,449,981
Scenario II	$38,961,078	$4,344,167	$23,880,443	$67,185,689

Statewide Water/Energy Savings Derived from Conservation Scenarios in 2060

	Water Saved From Conservation	Energy Saved From Water Conservation	Water Saved From Energy Reductions	
	MG	GWh	Consumptive Use (MG)	Withdrawals (MG)
Scenario I	45,598	102	46	72
Scenario II	68,232	146	65	103

(water savings directly resulting from state and federal implementation of plumbing codes requiring individuals to install water efficient plumbing fixtures as a part of the Energy Policy Act), metering (identifying and reducing the loss of non-revenue water), conservation water rates (tiered rate structures), and conservation education programs. Scenario II (substantially expanded conservation measures) involves all measures in Scenario I plus more aggressive metering and non-revenue water loss reduction, and the implementation of a high efficiency plumbing code ordinance that provides water savings beyond what passive conservation alone could achieve.

Water conservation in the M&I sector also translates into other savings that were analyzed as a part of the OCWP. Financial savings are associated with a reduced volume of water being treated and delivered. In order to estimate the benefits of reductions in water demands, a review of water treatment plant production and of municipal budgets in Oklahoma was completed for three cities: Stillwater, Ardmore and Edmond. The results of this analysis suggest that the cost of delivering one million gallons (MG) of treated groundwater ranges from $157-$550 per MG, and for surface water sources from $330-$1,100 per MG (Surface water sources typically cost more to produce than groundwater sources due to more extensive treatment requirements). The average direct operational production costs were estimated to be $354 per MG for groundwater sources and $696 per MG for surface water sources.

Given the results of Scenario I and II water savings and given the proportion of surface water to groundwater use for M&I demands, utility savings from conservation can be estimated by multiplying the direct operational cost by the amount of water saved from each scenario. Under Scenario I, statewide savings associated with reducing water production in the public-supplied M&I sector are roughly $26 million for surface water sources and $2.9 million for groundwater. Under Scenario II, the statewide savings for reducing surface water production could be as much as $39 million and for reducing groundwater production approximately $4.3 million.

Cost savings associated with reduced wastewater treatment were also assessed. To determine the reductions of wastewater treated by wastewater treatment (WWT) plants, only the public-supplied residential sector water use was considered. Analysis of water savings in 2060 resulted in reductions of treated wastewater totaling 83,377 AFY (27,180 MG) for Scenario I and 107,567 AFY (35,026 MG) for Scenario II. A review of the previously mentioned municipal budgets and corresponding WWT plants suggests the average unit cost of wastewater treatment in these three cities was $681 per MG of wastewater and was assumed to be the average unit cost of wastewater treatment throughout Oklahoma. Multiplying the per unit cost of wastewater treatment with the estimated reduction of wastewater results in wastewater savings associated with conservation programs: approximately $18.5 million under Scenario I and $23.9 million under Scenario II.

Another significant benefit of water conservation is the reduction of energy needed to produce less water. A reduction in water demand decreases the energy needed to provide water. Eighty-five percent of the energy involved in the initial treatment and distribution of water is for pumping requirements. Groundwater sources typically require 30% more electricity than surface water on a per unit basis due to increased pumping requirements.

Based on several studies citing national averages, Oklahoma energy costs for water production were assumed to be 1,400

Statewide Demand Projections and Water Savings for Irrigation Conservation Scenarios

	2020	2030	2040	2050	2060
	AFY				
Baseline	775,661	806,112	836,562	859,932	897,464
Scenario I	716,070	744,512	772,953	794,781	829,837
Scenario II	608,146	631,340	654,535	672,335	700,923
Change from Baseline (AFY)					
Scenario I	59,591	61,600	63,609	65,151	67,628
Scenario II	167,514	174,771	182,028	187,597	196,541

Impact of Combined Conservation Activities on Gaps and Storage Depletions

Source	Baseline Shortage Amount	Total and Percent Reduction from Baseline Shortage Amount			
		Scenario I		Scenario II	
SW	75,240 AFY	18,810 AFY	25%	23,980 AFY	32%
AGW	39,980 AFY	12,474 AFY	32%	22,554 AFY	59%
BGW	92,710 AFY	13,906 AFY	15%	73,784 AFY	78%

Reduction in the Number of Basins with Gaps and/or Storage Depletions

	Number of Basins with Gaps		
	Surface Water	Alluvial Groundwater	Bedrock Groundwater
Baseline	55	64	34
Scenario I	42	51	26
Scenario II	33	41	23

Kilowatt hours (KWh) per MG of water for surface water and 1,800 KWh per MG for groundwater. Thus, energy saved in conserving 45,498 MG under Scenario I would be 67.12 gigawatt hours (GWh) and energy saved in conserving 68,232 MG under Scenario II would be 100.4 GWh.

Reducing the amount of wastewater that needs treatment also saves energy. Energy required to recover and treat wastewater ranges from 955-2,500 KWh per MG depending on the treatment technique. The most common treatment technique is activated sludge with an average energy requirement of 1,300 KWh/MG treated. This energy requirement was assumed to be the energy cost of wastewater treatment in Oklahoma. Given the previously stated amount of wastewater abated from conservation Scenarios I and II, the amount of electricity saved from abatement of wastewater treatment is 35.33-45.57 GWh of energy depending on the conservation scenario. The amount of energy saved from conserving water is the sum of energy saved from initial water production and wastewater treatment. For Scenario I, the statewide reduction in energy demands is 102 GWh and for Scenario II it is 146 GWh.

A reduction in the amount of energy needed to produce less water and treat less wastewater also reduces the amount of water needed by thermoelectric power plants. In Oklahoma, more than 93% of electricity produced is from thermoelectric plants using natural gas or coal products as their primary fuel source. According to the OCWP analysis, 775 gallons of water are withdrawn for every megawatt hour (MWh) of electricity produced in Oklahoma. Based on estimated return flows, the actual consumptive use of water in thermoelectric power plants was assumed to be 480 gallons per MWh.

Given these facts and analysis, the total reduction in water withdrawals associated with the decrease in power production range from 72 MG for Scenario I and 103 MG for Scenario II. The decrease in consumptive use associated with this power reduction is 46 and 65 MG under Scenarios I and II, respectively.

Crop Irrigation Conservation Measures

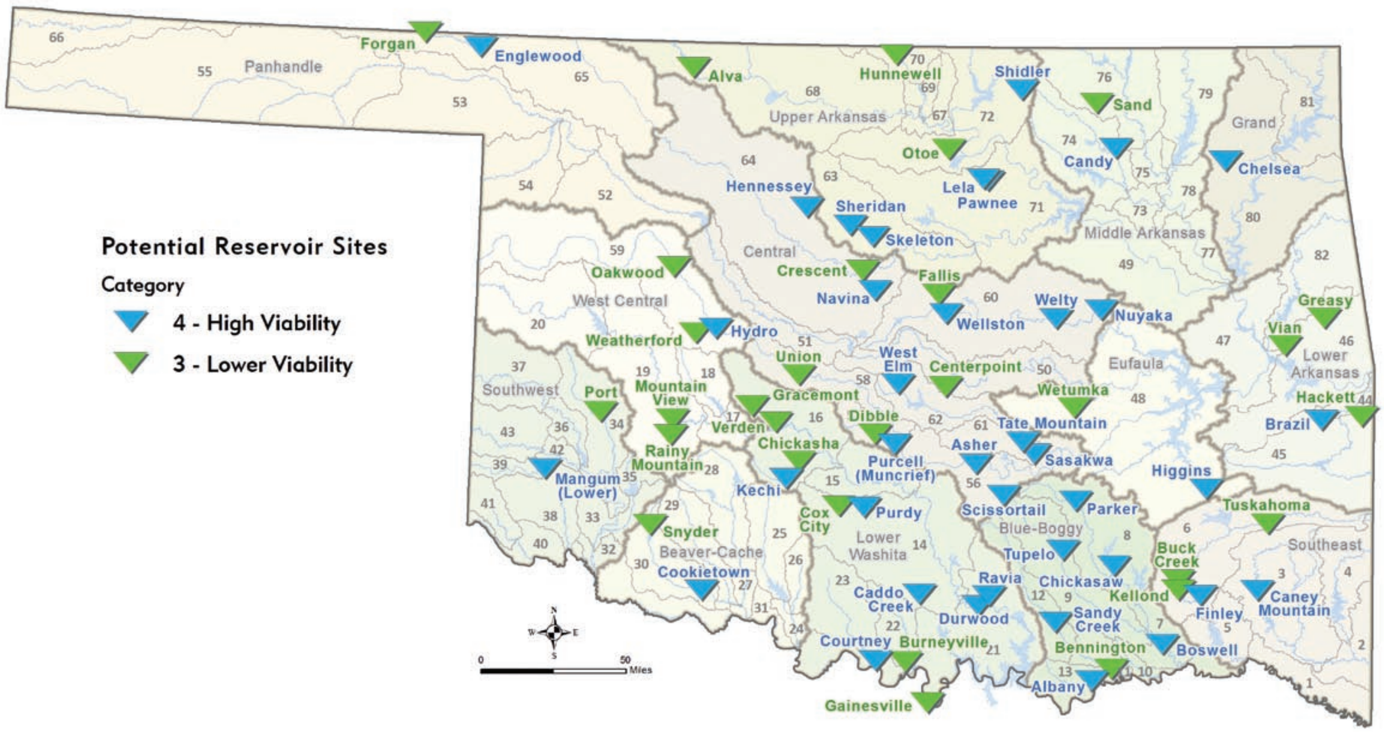
Crop irrigation conservation measures were also evaluated under moderately and substantially expanded scenarios. These were developed based upon patterns of current conservation and factors affecting future conservation activities including trends in regional irrigation practices, recent improvements of water conveyance systems, ease and cost effectiveness to farmers, and farming economics.

Agricultural irrigation water demand is driven by numerous factors such as acreage and type of crop irrigated, irrigation system type, seasonal rainfall, water availability, and fuel and commodity prices. Water savings can be achieved through a number of methods including implementing more efficient irrigation methods, shifting from water intensive to water efficient crops, and shifting to dryland production. These activities have differing economic, environmental, and political impacts and have various likelihoods of implementation.

Improvements in irrigation system deliveries reduce on-farm system losses, thus reducing the amount of water applied to the irrigation scheme. There are three main types of irrigation systems, each with unique efficiencies and options for improvement: sprinkler, surface, and micro-irrigation. Field application efficiencies of these systems assumed for the baseline forecast are 85%, 64%, and 89%, respectively.

Scenario I, moderately expanded conservation measures, included analysis of trends in: (1) irrigation efficiency related

Potentially Viable Reservoir Sites



to increased use of more efficient sprinkler irrigation systems statewide, (2) improvements in field application efficiency in surface (flood) irrigation systems, and (3) increased use of micro-irrigation technology in certain counties of southwest Oklahoma.

In Scenario I, the following future scenarios (beginning in 2015) were considered: (1) field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties increasing to 80%; (2) 10% of land irrigated by surface irrigation shifting to micro-irrigation in Harmon, Jackson, Tillman, and Kiowa counties; and (3) all sprinkler systems having a field application efficiency of 90%, representing implementation of low energy precision application (LEPA) nozzles on existing sprinkler systems. Additionally, it is assumed that water saved through conservation activities will not be used elsewhere such as expanding the number of irrigated acres.

Scenario II, in addition to those activities assessed in Scenario I, evaluated water demand reductions related to shifting to less water-demanding crops. Specifically, all acres of corn for grain and forage crops (including alfalfa and pasture grass) were shifted to grain for sorghum beginning in 2015. While it is highly unlikely that all water-intensive crop production will cease, this analysis allows for full consideration of these "what if" scenarios.

Statewide Impacts of Conservation Measures

These expanded conservation scenarios for both the M&I and Crop Irrigation demand sectors show significant promise in their potential to eliminate or at least reduce gaps and storage depletions in all basins across Oklahoma.

Potential Reservoir Development

A substantial number of potential reservoir sites have been evaluated in Oklahoma since statehood—particularly in the 1960s through 1980s. While significant economic, environmental, cultural, and geographical constraints may limit the construction of new reservoirs, significant interest exists in assessing potential sites to meet various needs, particularly those relating to regional water supply development.

To provide Oklahomans with readily accessible, updated information for most of Oklahoma's potential reservoir sites and as a tool for addressing long-range water needs for the OCWP analysis, the OWRB initiated the OCWP *Reservoir Viability Study*. Potential reservoir sites that have been studied to various degrees by the OWRB, Bureau of Reclamation (BOR), U.S. Army Corps of Engineers (USACE), Natural Resources Conservation Service (NRCS), and other public or private agencies were re-examined throughout the state. Sites of particular interest were those identified on a 1966 potential reservoir site map compiled by the OWRB and other state and federal partners, as well as updated sites recognized in the *1980 OCWP* and *1995 OCWP Update*.

The principal elements of the *Reservoir Viability Study* included the following:

- Extensive literature search;
- Identification of criteria to determine a reservoir's viability;
- Creation of a database to store essential site information;
- Evaluation of every identified site;

- Geographic Information System (GIS) mapping of the most viable sites;
- Aerial photograph and map reconnaissance of lake sites to identify cost drivers;
- Screening of environmental, cultural, and endangered species issues;
- Estimates of updated construction costs on a consistent cost basis; and
- Assessment and categorization of viability.

Historical data, plans, and maps revealed more than 100 reservoir sites in Oklahoma that fall within the study's scope. Reservoir sites were categorized into five general classifications of viability, recognizing that there may be significant variation among candidates within each category:

- Category 0—Some reservoir sites were identified by location on the 1966 OWRB map; however, no background or study data could be located for these sites.
- Category 1—Numerous reservoir sites were briefly described in regional master plans. Some data was reported but essential elements of information such as location, dam configuration, drainage area, etc. were not available. These reservoirs may or may not be viable, but there is insufficient information available for a proper determination.
- Category 2—This category includes sites that may have significant data available for analysis, but have substantial obstacles that could prevent construction, such as endangered species. Future events, such as removal of a species from the endangered list, could move a reservoir to another category.
- Category 3—Site information is sufficient for an analysis, but one or more factors—such as poor water quality, low dependable yield, high cost per unit, etc.—indicate reservoir sites that are slightly less desirable than those in Category 4. As with the other categories, future events could change the ranking, but with the current information, these reservoirs are generally less viable for development than the Category 4 sites.
- Category 4—These reservoirs sites have undergone extensive evaluation and were determined to be the most viable candidates for future development. As with the other categories, future events could change this ranking.

Where appropriate, Category 3 and 4 sites were considered in the assessment of the "Out-of-Basin Supplies" or "Reservoir Use" options in the 13 Watershed Planning Region Reports.

Results of this study present only a cursory examination of the many factors associated with project feasibility or implementation and do not indicate an actual need or specific recommendation to build any project. However, reservoirs were shown to be an effective option in many basins to alleviate projected water shortages. The identified Category 3 and 4 sites should serve as excellent starting points for future basin and regional supply sources. Detailed investigations would be required in all cases to verify feasibility of construction and implementation. The complete OCWP *Reservoir Viability Study* is available on the OWRB website.

Marginal Quality Water Use

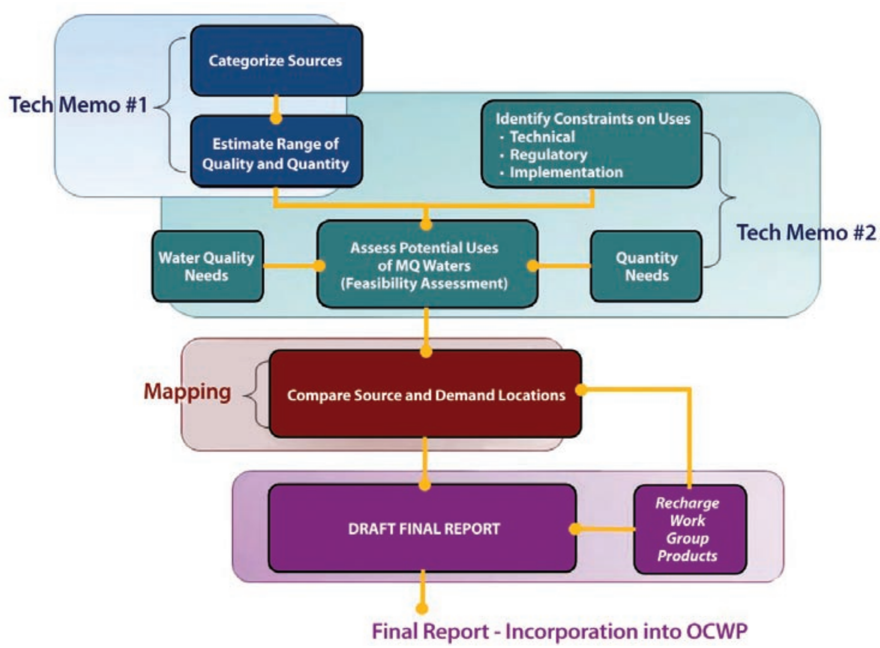
As Oklahoma's water needs continue to grow, additional sources of water must be considered, including supplies that historically have not been tapped to meet demand. The Oklahoma Legislature passed Senate Bill 1627 in 2008 requiring the OWRB to establish a technical workgroup to analyze the potential for expanded use of marginal quality water (MQW) from various sources throughout Oklahoma. The group included representatives from state and federal agencies, industry, and other stakeholders.

Categories of Marginal Quality Water and Study Approach

Through facilitated discussions, the workgroup defined MQW as water that historically may have been unusable because of technological or economic issues with diversion, treatment, and/or conveyance. This may include waters that would not typically be considered for beneficial uses, such as municipal, industrial, or agricultural supplies. Five categories of MQWs were identified for further characterization and technical analysis:

- Treated wastewater effluent: wastewater that has gone through primary, secondary, and/or tertiary treatment processes to meet regulated discharge limits for a variety of water quality parameters (limited to municipal discharges to surface waters).

Approach for Assessing Uses of MQW



- Stormwater runoff: runoff from impervious surfaces such as driveways, sidewalks, and streets that is prevented from naturally entering the hydrologic cycle and oftentimes conveys debris, chemicals, sediment, and other pollutants to storm sewer systems or directly into a receiving waterbody. Stormwater may or may not be treated through best management practices (BMPs) prior to entering water bodies.
- Oil and gas flowback/produced water: water that returns to the surface during initial oil and gas well development and hydraulic fracturing is considered "flowback" while water that is a by-product of well production is "produced water."
- Brackish surface and groundwater: surface and groundwater sources that have higher salinity than freshwater, but less than seawater.
- Water with elevated levels of key constituents: sources of water that have concentrations of key constituents that would require advanced treatment before beneficial use, such as nitrate reduction/removal prior to public water supply use.

A phased approach was taken to meet the objectives of the legislation consisting of: (1) quantifying and characterizing MQW sources temporally through 2060 and geographically across the state, (2) assessing constraints to MQW use, and (3) matching projected future demands across Oklahoma with MQW sources and assessing the feasibility of utilizing MQW.

Water demands and supplies, including MQW, can be evaluated using a myriad of different boundaries and geographic extents. To allow direct use of the OCWP supply and demand data, as well as integration of MQW analyses into the overall OCWP, the MQW analysis used the 82 OCWP planning basins for analyses. The MQW assessments and analyses included characterization of the identified sources of MQW and estimation of the range of available quality and quantity. Innovative OCWP tools were used to quantify MQW availability. For example, the Oklahoma H2O tool was used to estimate return flows from M&I water use and quantify the amount of treated effluent that might be available for reuse in each basin. The estimates on the available quantities and a summary of typical water quality for each of the identified MQW categories are discussed in detail in the OCWP *Marginal Quality Water Issues and Recommendations* report.

Constraints and Opportunities

Each source category of MQW was considered in terms of constraints on its use. The following technical, regulatory, environmental, and implementation constraints were identified:

- **Technical Constraints:** Technical constraints on uses of MQW could include (1) infrastructure needs, such

Constraints on Using MQW Sources

Category	Possible Constraints			
	Technical	Regulatory	Environmental	Implementation
Treated Wastewater	• Treatment to required quality • Higher dissolved solids • Emerging contaminants (e.g., Pharmaceuticals and Personal Care Products) • Infrastructure needs	• No detailed Oklahoma standards for reuse • Dependent on use • Downstream water rights and domestic use	• Reduced receiving water flow	• Cost relative to raw, fresh, potable water options • Public perception
Stormwater Runoff	• Collection/distribution system • Intermittent supply and associated storage needs • Variable and extreme water quality	• Downstream water rights and domestic use • MS4s	• Reduced receiving water flow	• Cost relative to raw, fresh, potable water options
Oil and Gas Produced Water	• Location relative to demand • Mobile operations/ mobile treatment • Water quality/treatment needs	• Discharge regulations • Storage and transportation • Permitting	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land • Liability of storing, treating, or transporting
Oil and Gas Flowback Water	• Location relative to demand • Mobile operations/ mobile treatment • Temporary supply • Relatively small volume • Water quality/treatment needs	• Discharge regulations • Storage and transportation • Permitting	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land • Liability of storing, treating, or transporting
Brackish Water	• Treatment/residuals disposal • Depth of wells • Location relative to demands • Sustainability (groundwater sources) • Reliability (surface water sources)	• Discharge regulations • Storage and transportation • Permitting	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land
Water with Elevated Levels of Key Constituents	• Treatment	• Potable quality standards and treatment requirements	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception

Feasibility of MQW Sources to Meet Water Demands

Category	MQW Source Category				
	Treated Wastewater	Stormwater Runoff	Oil and Gas Flowback/Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
M&I - potable	⊖ WQ, PUB	✗ WQ, LOC, REL	✗ WQ, LOC, PUB	⊖ AT	⊖ AT, PUB
M&I - non-potable	✓ WST	✓ WST, PT	✗ LOC	⊖ AT	✓ CT, AT
Self-Supplied Residential	⊖ WQ, LOC, PUB	✗ WQ, LOC	✗ WQ, LOC, PUB	⊖ WQ	⊖ WQ, PUB
Self-Supplied Industrial	✓ WST	⊖ LOC, PT, CT	✗ WQ, LOC	⊖ CT, AT	⊖ CT, AT
Thermoelectric Power	✓ WST	⊖ LOC, PT, CT	✗ WQ, LOC	✓ CT, AT	✓ CT, AT
Oil and Gas	✗ LOC	✗ LOC	⊖ CT, AT, PT, WQ, LOC, REL	⊖ CT, AT, PT, WQ, LOC, REL	✓ CT, AT, PT, WQ, LOC, REL
Crop Irrigation	✓ LOC, PUB	✗ LOC	✗ WQ, LOC	⊖ CT, AT	✓ CT, AT
Livestock Watering	⊖ LOC	✗ LOC	✗ WQ, LOC	⊖ AT	⊖ CT, AT

Legend

✓ Potentially feasible, depending on site-specific conditions

⊖ Less feasible, depending on site-specific conditions

✗ Not feasible on a wide-scale basis for indicated reason(s)

WST May require additional Wastewater or Stormwater Treatment beyond that required for discharges, depending on specific use
PT Passive treatment may be required
CT Conventional treatment may be required
AT Advanced treatment may be required
WQ Treated water quality requirements would prohibit use or make treatment economically infeasible for indicated user
LOC Location of supply may not be near location of significant demand
REL Reliability of supply inadequate to meet demand without significant storage infrastructure
PUB Public Perception

as enhanced treatment for reuse of effluent, collection and distribution systems for stormwater, or mobile/temporary treatment facilities for oil and gas operations, (2) treatment requirements, (3) variable or finite supplies, such as precipitation-related supplies for stormwater, or non-renewable aquifers for brackish groundwater, and (4) supply location relative to demand.

- **Regulatory Constraints:** Regulatory requirements for MQW are dependent on the intended use. Currently, there are no detailed reuse standards in Oklahoma and only limited guidance for treatment requirements for MQW sources. Any water intended for potable use must meet drinking water standards. Similarly, any water that would eventually be discharged would be required to meet permit requirements (National Pollutant Discharge Elimination System [NPDES], Municipal Separate Storm Sewer System [MS4], etc.). Regulatory constraints may be placed on the use of water based on existing water rights, domestic uses, and other similar situations. Additional regulatory constraints may be placed on the storage and transportation of MQW in the future.
- **Environmental Constraints:** Environmental constraints could include the disposal of treatment residuals, impacts of decreases in instream and downstream flows (water quality and habitat effects), and subsidence impact on fresh water from pumping deep aquifer brackish water supplies.
- **Implementation Constraints:** The major overarching constraints for the use of MQW sources are public perception and costs. Public perception refers to a negative perception of using the water source, which may be contrary to the available technical information. Although driven in large part by site-specific conditions, the historic use of non-MQW sources (i.e., raw water, fresh water supplies, and/or potable options) instead of MQW sources is likely due to the cost of MQW use relative to the traditional non-MQW source options. Costs can include storing, treating, or transporting MQW, including the associated liability costs. Availability of land may be a constraint to implementation as well.

Water needs were characterized for each of the OCWP seven water use sectors based on the water demand projections developed in the OCWP. Water quality needs for each sector were characterized based on available literature and industry-specific knowledge.

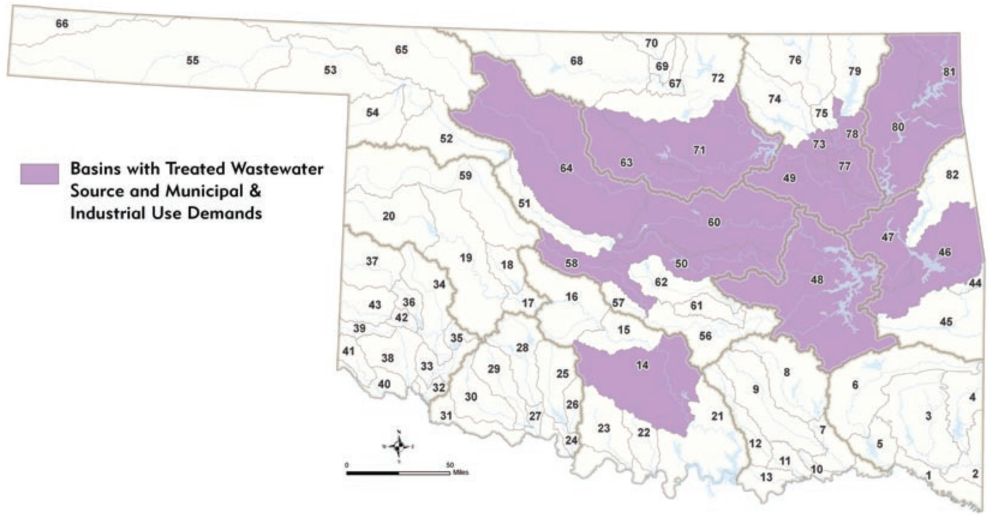
Based on the analysis of potential constraints and needs of Oklahoma's seven water demand sectors, a screening matrix of the potential feasibility for using MQW supplies to meet some or all of the water needs of each of Oklahoma's major water use sectors was created. The matrix also provides information on the level of treatment that may be needed to put the MQW sources to beneficial use by water use sector. With input from the MQW workgroup, the matrix evaluation was conducted on a qualitative, non-geographical basis as an initial screening of the relative feasibility of each supply/demand permutation.

Drawing conclusions regarding the feasibility of supply/demand combinations on a broad, statewide basis is challenging. Localized conditions and site-specific issues could cause the feasibility of using a given specific supply to be directly opposite of what is described here. Rather, this assessment is intended to serve as a guide for the relative feasibility of each MQW supply/demand combination on a categorical basis. This exercise helped facilitate an evaluation of more geography-specific opportunities to use MQW, shown through mapping.

Mapping performed for this evaluation used Geographic information System software to overlay basins with higher demand densities with basins that have relatively

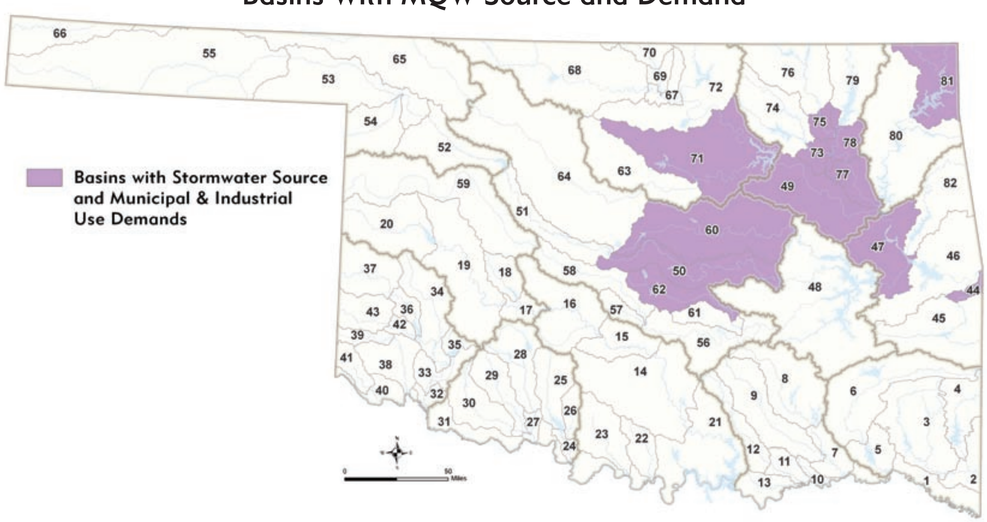
Treated Wastewater for M&I Non-Potable Use

Basins With MQW Source and Demand



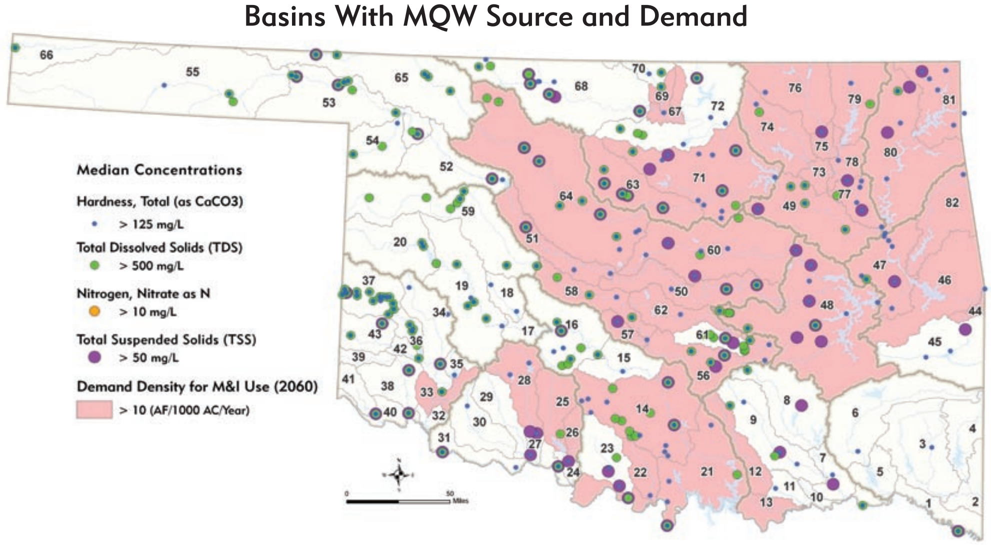
Stormwater Runoff for M&I Non-Potable Use

Basins With MQW Source and Demand



Waters With Elevated Levels of Key Constituents for M&I Non-Potable Use

Basins With MQW Source and Demand



higher supplies of MQW. Comparisons were made for each potentially feasible permutation of water demand sector and MQW source categories. Basins where these two geographic coverages converge are areas where there may be the greatest potential to meet a significant portion of future demand with MQW sources, and where further investigation into the use of MQWs may be warranted.

The accompanying maps indicate basins where the study found potentially feasible uses for marginal quality water (by type of MQW source and demand sector) as indicated by the green circle on the matrix. The complete set of maps for all MQW uses and all demand sectors can be reviewed in the OCWP *Marginal Quality Water Issues and Recommendations* report.

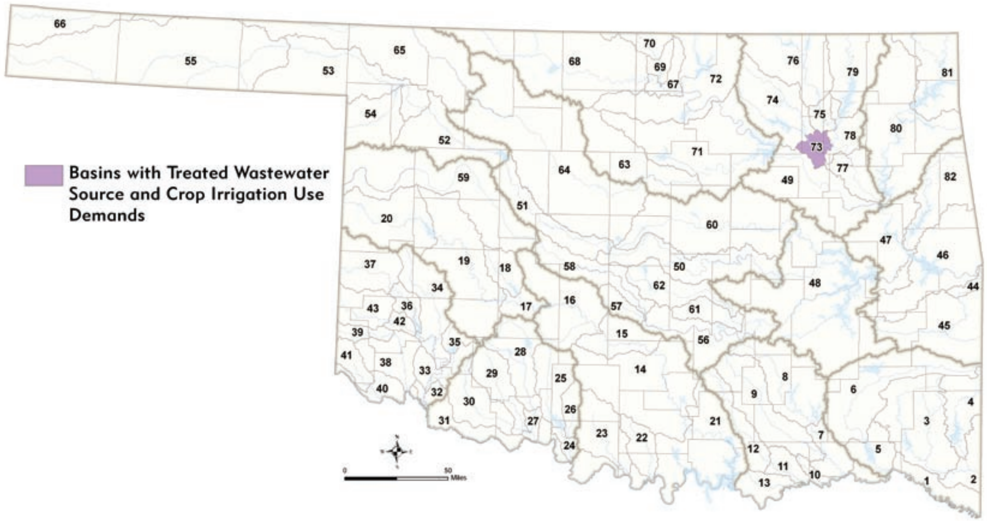
Conclusions and Recommendations

Opportunities for increased utilization of MQW supplies may exist at local and statewide levels for several combinations of MQW supply and Oklahoma's seven water demand sectors. Site- and project-specific conditions will affect the economics, technical viability, and user acceptance of every project. Historical limitations on the use of MQW to meet various water needs have likely been based on the economics of its use relative to other source-of-supply options. However, this statewide screening analysis provides insights into the relative viability of using MQW supplies to meet Oklahoma's future water needs.

Treated wastewater from municipal treatment facilities, often referred to as "water reuse," is a potentially viable source of supply for non-potable uses, rather than discharging the water into area streams. Because supplies are greater in and near

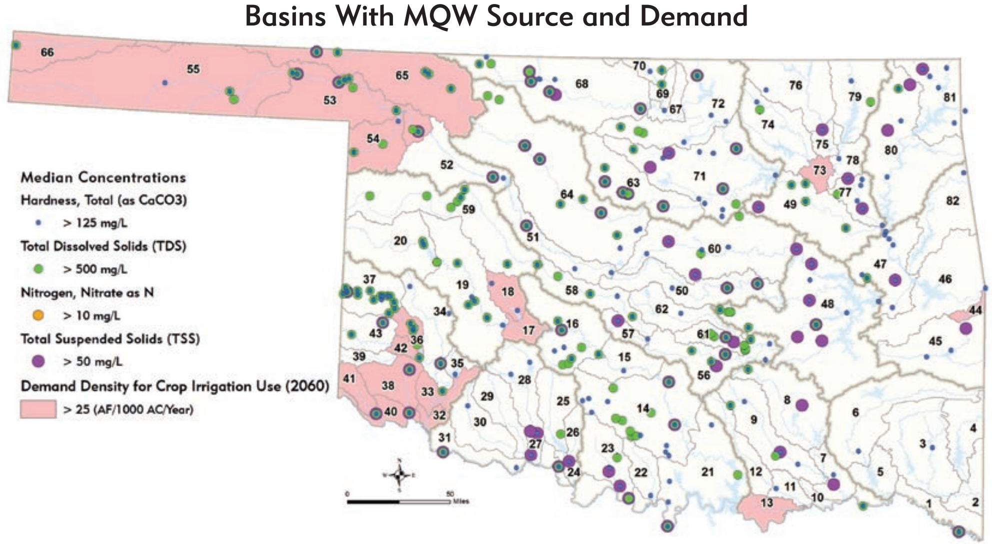
Treated Wastewater for Crop Irrigation Use

Basins With MQW Source and Demand



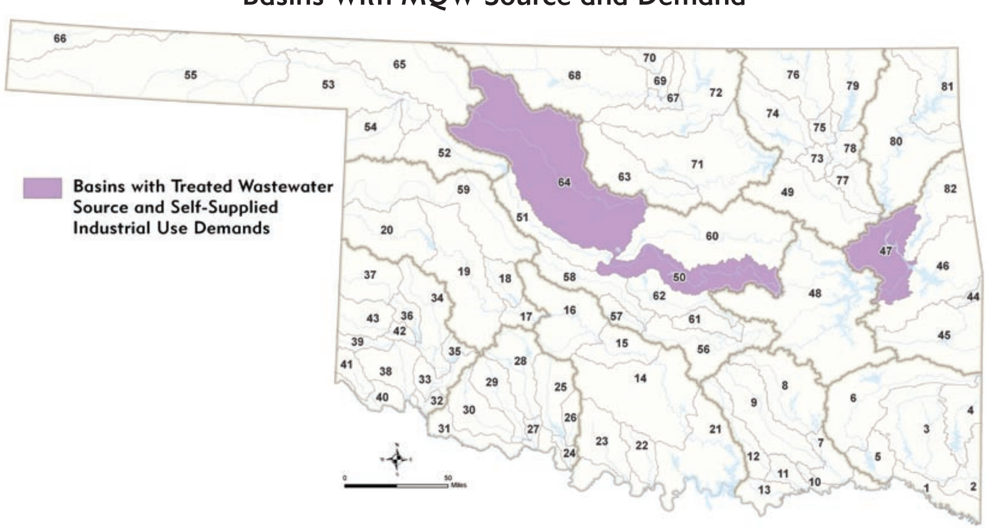
Waters With Elevated Levels of Key Constituents for Crop Irrigation Use

Basins With MQW Source and Demand



Treated Wastewater for Self-Supplied Industrial Use

Basins With MQW Source and Demand



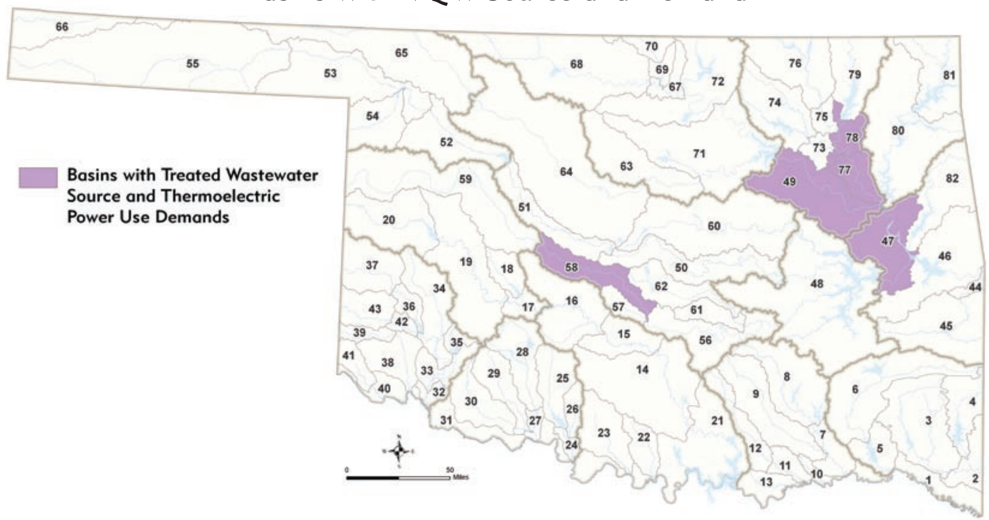
the state's cities and towns, M&I non-potable demand (e.g., landscape irrigation) and some industrial or power-generating facilities are likely to be the most cost-effective application for this source of MQW supply. Mapping showed that opportunities to use Treated Wastewater to meet the water needs of the M&I include the Oklahoma City metro area and areas to the east, and opportunities to meet other industrial (self-supplied and thermoelectric) use sectors' needs are located in the areas around Oklahoma City, Tulsa, and Muskogee. However, there is some use of treated wastewater currently taking place in other areas of the state, but at a smaller scale than the criteria chosen for this study. Any future uses of treated wastewater must consider the impacts to downstream water availability, needs, and water rights.

Stormwater collected in municipal storm sewer systems could be utilized, primarily for non-potable uses, where suitable storage could be provided to buffer the intermittent supply against the demand placed upon this source. Again, the more urban nature of this source of MQW supply suggests that its most cost-effective use will be in and around the state's communities and more highly-developed areas. Stormwater released to receiving waters (surface water or groundwater) was not considered in this evaluation. Areas of most opportunity for stormwater to be used for M&I, self-supplied industrial, and thermoelectric needs are located along a corridor between Oklahoma City, Tulsa, and Muskogee.

Oil and Gas Flowback Water is a relatively low volume while Produced Water can be a locally significant source of MQW, but utilization of this resource is likely to be limited by temporal, location, and water quality issues. In addition, treatment

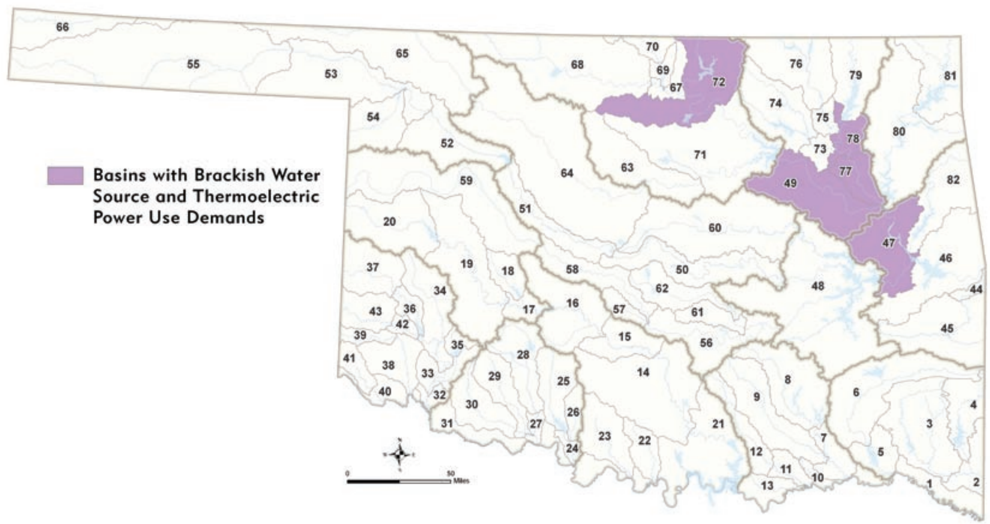
Treated Wastewater for Thermoelectric Power Use

Basins With MQW Source and Demand



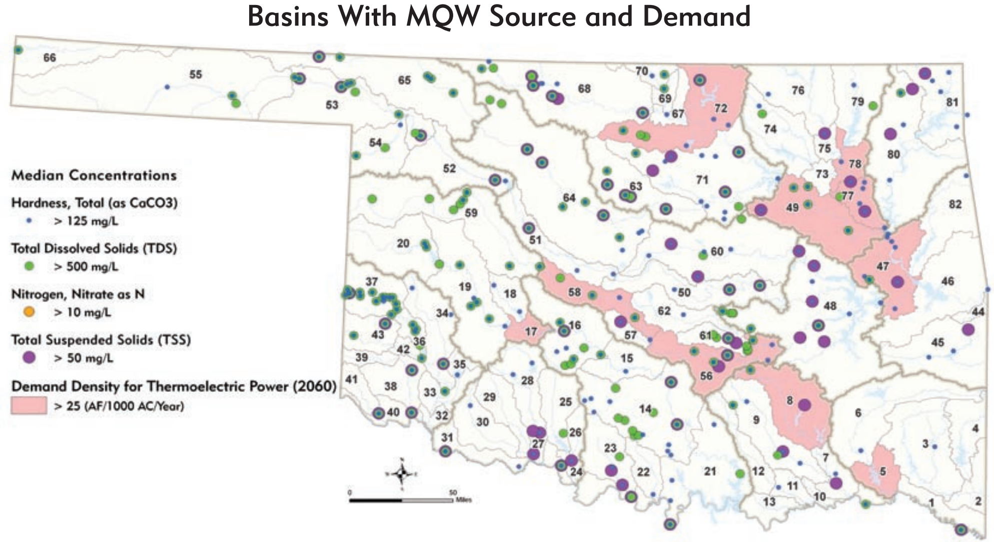
Brackish Water for Thermoelectric Power Use

Basins With MQW Source and Demand



Waters With Elevated Levels of Key Constituents for Thermoelectric Power Use

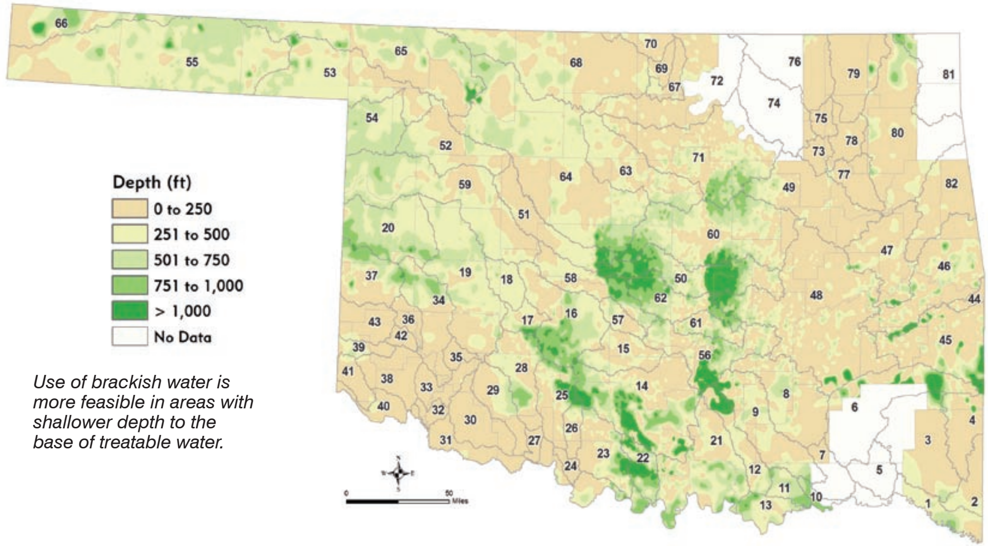
Basins With MQW Source and Demand



requirements, storage needs, and the location of significant water users' demand relative to oil and gas production activities may negatively impact the cost-effectiveness of using the water resource. Of Oklahoma's seven demand sectors, reuse of flowback and produced water to support the water needs of nearby oil and gas drilling, fracking, and secondary/tertiary recovery may potentially be the most viable opportunities from a technical and economic perspective. Oil and gas production activities are a major economic driver for the state and are expected to continue to occur across a wide geographic range in Oklahoma.

Depth to Base of Treatable Brackish Water

10,000 mg/L TDS



Use of brackish water is more feasible in areas with shallower depth to the base of treatable water.

Brackish Water would in most cases need advanced treatment to meet potable water quality standards. Advanced treatment incurs capital and operational costs that are significantly higher than traditional treatment technologies. The most viable users of brackish water supplies are likely public water suppliers (M&I demand) and industrial users who have the financial resources and technical capability to operate advanced treatment facilities, and who have limited alternatives for supply. Some of the more salinity-tolerant crops such as barley and wheat, and some livestock groups such as dairy and beef cattle, could potentially use brackish water supplies to meet their needs without treatment.

Mapping showed where higher demand for each sector is located relative to shallower brackish groundwater depths. The northeastern quadrant of the state shows that opportunities may exist to use brackish groundwater for M&I demand. A smaller portion of the northeast quadrant shows some basins where brackish groundwater may be easier to access to meet the needs of self-supplied residential users with point-of-use water treatment systems. Self-supplied industrial opportunities may exist northeast of Enid, near Muskogee and near Altus, while thermoelectric power opportunities may exist between Tulsa and Muskogee and northeast of Enid. There may be opportunity to offset crop irrigation demand with brackish groundwater sources in the southwest portion of the state. Livestock watering demand best matches up to brackish groundwater depths in northeast and western portions of Oklahoma. Again, the ability of brackish groundwater sources to meet livestock water demand is dependent predominantly on animal type.

Waters containing elevated levels of key constituents (as defined for this workgroup effort) are potential candidates for non-potable uses. Industry use of these MQW sources will be heavily contingent on the specific water quality needs of each industrial user. Potable use of waters with elevated levels of key constituents would require advanced treatment, which would likely only be cost-effective in situations where alternative supplies are not readily available.

These recommendations were set forth with the consensus that any application of a MQW source to meet demand should consider the impacts to downstream water availability, needs, and rights. In addition to the trends and opportunities identified, several recommendations were developed and discussed with the technical workgroup for future development of MQW.

- **Treated Wastewater:** The greatest near-term opportunity to increase the beneficial use of MQW is the use of treated effluent in urban settings for certain non-potable applications (irrigation of golf courses, for example). Public water suppliers and users should consider treated effluent reuse where it is both cost-effective and socially acceptable. The state should continue to support the development of more detailed reuse regulations to provide a framework for utilizing this MQW source while recognizing downstream uses of that water. Aquifer recharge is another potential use of this MQW that may warrant further investigation.
- **Stormwater Runoff:** The potential for storage and use of stormwater runoff to meet non-potable demand in urbanized areas in central and eastern Oklahoma should be further examined in light of site-specific issues and considering potential water rights issues related to downstream diversions. Focus areas should include locations where precipitation is relatively high and infrastructure exists to accommodate stormwater reuse applications.

- **<u>Brackish Water</u>**: The state should continue to follow developments in the ongoing USGS study to characterize areas where brackish groundwater is most readily accessible. Particular attention should be given to areas with projected water shortages and areas where predominant water uses may require less treatment (e.g., areas with salt-tolerant crops and livestock). Additionally, areas with shallower depth to the base of treatable water could be more feasible. Advances in treatment technologies, such as desalination, should be followed for potential application in the future. The deep well injection permitting process could be streamlined to facilitate the disposal of treatment residuals.
- **<u>Oil and Gas Flowback and Produced Water</u>:** Oil and gas producers in Oklahoma should be encouraged to continue to seek cost-effective opportunities to reuse flowback and produced water to help meet oil and gas drilling and fracking water needs.
- **<u>Waters with Elevated Levels of Key Constituents</u>:** The state and water users should continue to support research and development of advanced treatment technologies to facilitate the cost-effective use of this MQW source. Of all the sources of MQW evaluated, water reuse—beneficially using treated wastewater to meet certain demand—is perhaps the most commonly used MQW supply nationwide and has the most potential statewide. As users face greater and greater water supply challenges and as more water supply shortages are projected in our future, the beneficial use of our effluent is becoming a significant topic of discussion.

Artificial Aquifer Recharge

Artificial aquifer recharge (groundwater storage and recovery), defined as diversion of runoff or other viable sources of water into groundwater basins for storage and later use, could be an effective tool for managing declining or limited groundwater resources. In 2008, the Oklahoma Legislature passed Senate Bill 1410 (SB1410) requiring the OWRB to develop and implement criteria to prioritize potential locations throughout Oklahoma where artificial recharge (AR) demonstration projects may be most feasible. A workgroup of numerous water agencies and user groups was organized to identify locations in both alluvial and bedrock aquifer settings that would be most suitable for AR demonstration projects to help meet future water supply challenges. The following is a summary of the workgroup's findings. The complete OCWP *Artificial Aquifer Recharge Issues and Recommendations* report is available on the OWRB website.

The goal of the Phase 1 investigation was to identify locations in both alluvial and bedrock aquifer settings that would be most suitable for AR demonstration projects to help meet future water supply challenges. If funded, a future Phase 2 would implement the recommendations from Phase 1, including pilot project field demonstration(s) of AR. Phase 1 investigations primarily sought opportunities to implement a demonstration project in conjunction with a public water supplier, but other users could also benefit from a demonstration-scale or full-scale recharge project.

The OWRB has successfully demonstrated AR in the Blaine aquifer in southwest Oklahoma. The sites were in karst aquifers and utilized gravity flow infiltration and recharge methods. Sites in this area were not considered in this study since AR has already been demonstrated in that region.

<u>Site Screening Process</u>

Criteria were developed for both a preliminary screening and a more detailed ranking process. The purpose of the preliminary screening was to eliminate many areas from further consideration based on a relatively simple application of a small number of criteria. All sites not eliminated through the preliminary screening would likely be suitable for an AR demonstration project. The more detailed ranking process identified the most feasible of the suitable sites flagged through the preliminary screening.

The preliminary screening was divided into a fatal flaw analysis and a threshold analysis. The fatal flaw analysis applies a limited set of criteria that, if the necessary characteristics are not present, would eliminate regions or aquifers from any further analysis. The fatal flaw screening criteria were developed to be able to use readily available information and a relatively simple process for analyses of data. The threshold level screening was used to expedite the detailed analyses by eliminating additional aquifers or areas from further consideration based on several key factors. Based on discussions workgroup discussions and review of previous regional studies and national guidelines and standards set forth by government and professional organizations, criteria were selected for fatal flaw, threshold screening, and detailed ranking.

Several sites were screened out through the fatal flaw analysis, resulting in 15 alluvial aquifer sites and 15 bedrock sites. The threshold analysis screened out an additional 15 sites, resulting in 6 alluvial sites and 9 bedrock sites.

A detailed ranking was then used to determine the most suitable sites for the pilot project through an objective scoring process. Based on the information gathered for each recharge area, individual criteria were compared among all recharge areas, and an appropriate score (high, moderate, low) was assigned to each recharge area for each criterion. In some cases, further differentiation was deemed appropriate and a moderately high or moderately low score was assigned for a given recharge region. These factors were assigned a raw score from 1 to 5 with 1 being not favorable and 5 highly favorable. Criteria were assigned weights to indicate their relative importance, which was determined by a voting exercise of workgroup members. Final scores for each recharge site were determined by multiplying the raw score by the weight and summing the weighted scores for all criteria.

<u>Recommended Sites</u>

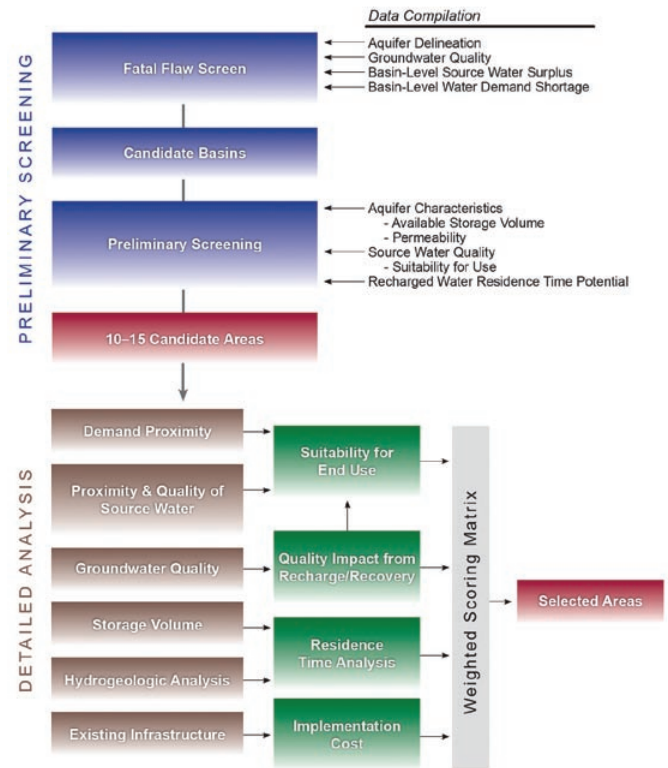
Three short-listed sites (site 12, Ada; site 42, Eakly; and site 19, Woodward) were identified by the workgroup and discussed in detail. The workgroup expanded the recommended number of sites to include two alternates in case local interest is low or new information from follow-up investigations at the recommended sites reveals a limiting factor. Therefore, the workgroup selected site numbers 15 (Durant) and 30 (Enid).

These sites were added as alternatives because they were consistently in the top group of sites in the rankings under various criteria weightings tested at the workgroup meeting.

Recharge Region 12 is located near the Town of Ada, with the Blue River providing a water source and the Arbuckle-Simpson aquifer providing storage. The nearest gage of the probable diversion for the project is located approximately 17 miles downstream. There are no upstream gages to help better quantify source availability, but based on basin size, the source location appears to have an adequate supply. The Town of Ada has existing wells in the vicinity of the recharge region, making it a good candidate for a recharge project. Additionally, there is plentiful storage, and the residence time is appropriate for a pilot project. Given the channelized nature of the karst aquifer, specific site investigations would be required to ensure the recharged water could be recovered. The Blue River had minimal maximum contaminant level (MCL) exceedences and low TDS concentrations, suggesting that pretreatment would not be required. Also, the Langelier indices for the Blue River and Arbuckle Simpson aquifer provided one of the closest pairings of all recharge regions. Perhaps the most negative aspect of Recharge Region 12 is the requirement of a one-mile long pipeline to convey water from the source to the recharge area. However, the majority of recharge regions that were identified included this requirement, and most would require a longer pipeline than Recharge Site 12.

Recharge Region 42 is located near the Town of Eakly, with Lake Creek providing a water source and the Rush Springs aquifer providing storage. Demand for the entire town is approximately 250 AFY, so a pilot project could potentially meet the entire demand for Eakly. Flows in Lake Creek are subject to regulation due to nearby Fort Cobb Reservoir, which may limit the supply availability. However, the relatively small amount of water required for the project may be negligible compared to the reservoir yield requirements. Overall, Lake Creek appears to be an adequate source, even during drought years. The Town of Eakly has two existing wells in the vicinity of the recharge region, making it a good candidate for a recharge project. Additionally, there is plentiful storage, and the residence time is appropriate for a pilot project. There was limited water quality data available from Lake Creek, but nearby Cobb Creek exceeded MCLs infrequently. Only one sample was collected from Cobb Creek for TDS, and it slightly exceeded the MCL. Thus, it is strongly recommended that further water quality characterization be completed prior to implementing a pilot project at this recharge region to help determine the need for pre-treatment. The Oklahoma Corporation Commission (OCC) provided oil and gas well locations in the area. The nearest wells were more than a mile from the recharge region, thus not considered to be potentially detrimental to the site. Recharge Region 42 would also require a two-mile long pipeline to convey water from the source to the project, which is longer than that required for Recharge Region 12.

Artificial Recharge Site Screening Process



Artificial Recharge Site Screening Levels and Criteria Weighting Factors

Category	Criteria	Screening Level		
		Fatal Flaw	Threshold	Detailed
Demand	Frequency	X	X	X
	Proximity	X	X	X
	Density			X
Source Water	Proximity	X	X	X
	Availability		X	X
	Quality for Non-Degradation		X	X
	Regulatory Challenges		X	X
Hydrogeologic Suitability	Available Storage Volume and Ability to Meet Local Demand		X	X
	Transmissivity		X	X
	Residence Time/ Distance to Discharge		X	X
Groundwater Quality	Native Quality	X	X	X
	Geochemical Interactions with Source Water			X
Cost	Recharge Method (Capital and O&M)			X
Project Impact	Qualitative Considerations			X

Artificial Recharge Site Scoring Guidelines for Detailed Ranking

Criteria	Factors for High Score	Factors for Moderate Score	Factors for Low Score
Demand Proximity (distance from recharge area)	Within 1 mile	Approximately 1.5 miles	Greater than 2 miles
Source Proximity (distance from recharge area)	Within 1 mile	Approximately 1.5 miles	Greater than 2 miles
Available Freeboard and Ability to Meet Demand	Plentiful volume for meeting the associated demand; no areas will raise water level to less than 15 feet below ground surface	Likely sufficient volume for associated demand, but uncertainty exists	Not enough volume to meet the associated demand; may raise the water level to less than 15 feet
Demand Density (number of wells)	Greater than 10 PWS wells within 1 mile	5 to 10 PWS wells within 1 mile	Less than 5 PSW wells within 1 mile
Source Quality for Nondegradation	Similar concentrations as groundwater or lower concentrations that will improve groundwater; no MCL exceedences; low TDS	Borderline TDS; few exceedences of MCLs	Quality will degrade groundwater; high TDS; many MCL exceedences
Native Groundwater Quality	Low TDS (<500 mg/L); no MCL exceedences	Borderline TDS; few exceedences of MCLs	High TDS (>500 mg/L); many exceedences of MCLs
Geochemical Interactions of Source and Groundwater	Similar Langelier Indices[1] (source and groundwater within 0.5 units); similar pH values	Langelier index unable to be computed, but similar pH and hardness values	Langelier indices that are greater than 0.5 units different; largely different pH or hardness values
Transmissivity	T>1,000 ft2/d	T>500 ft2/d, but less than 1,000 ft2/d	T<500 ft2/d
Residence Time	Less than 10% loss in 180 days, >480 days to 25% loss	10 to 25% loss in 180 days, 180 to 480 days to 25% loss	>25% loss in 180 days
Cost (O&M)	No pretreatment required; gravity flow delivery; spreading basin use	Combination of some more expensive and less expensive components	Pretreatment required; Aquifer Storage and Recovery wells (ASR) utilized; force mains required
Cost (capital)	Gravity flow delivery; ASR well retrofit	Spreading basin in rural area	Spreading basin near municipality; ASR well construction; pipeline construction
Qualitative Considerations	Project size meets 100% of demand	Project size meets 25% of demand	Project size meets <10% of demand

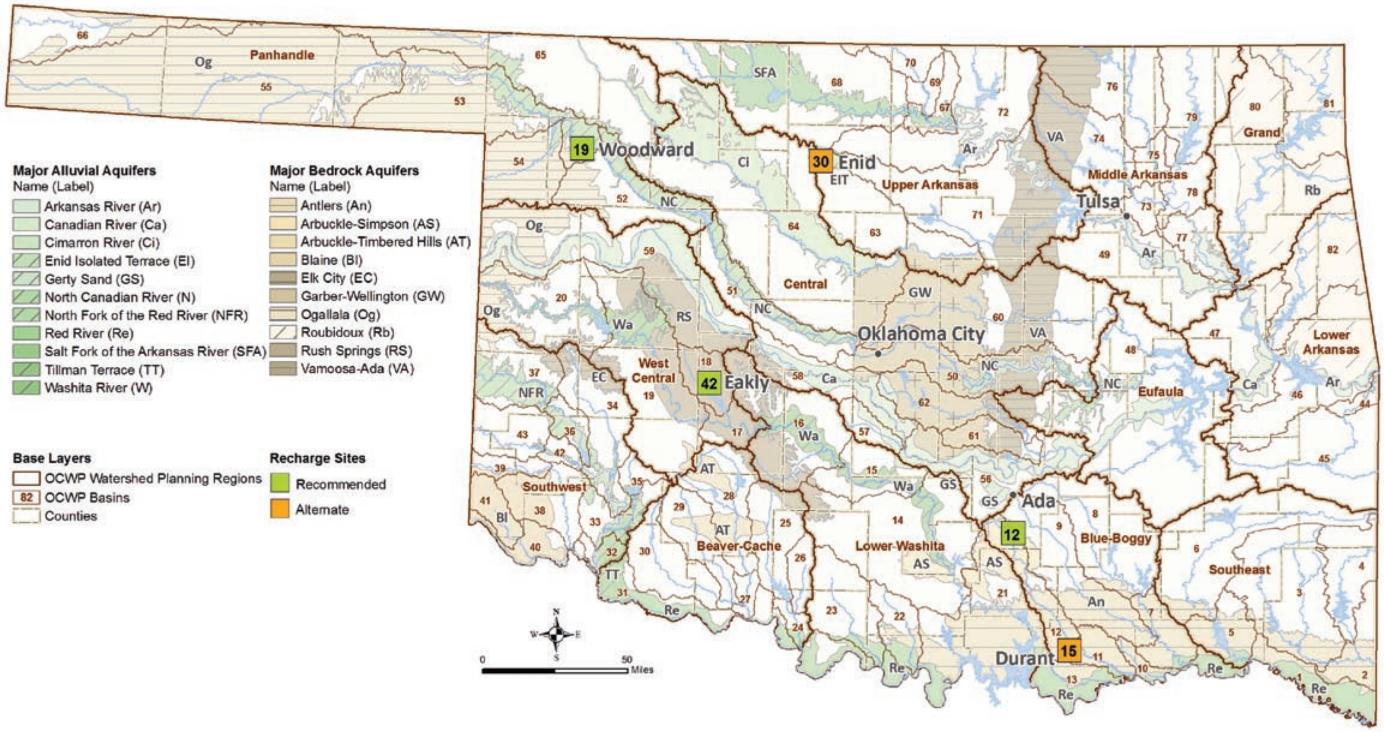
1 The Langelier Saturation Index is an equilibrium model that indicates the degree of saturation of water with calcium carbonate for water treatment purposes.

Artificial Recharge Site Scoring Matrix (Sorted by Rank)

Recharge Region Number	Nearby Municipality	Source Availability	Demand Proximity	Source Proximity	Available Storage Volume	Demand Density	Source Water Quality	Native GW Quality	Geochemical Interactions	Transmissivity	Residence Time	Cost - O&M	Cost - Capital	Qualitative Considerations	Weighted Score
	Weighting Factor	1.8	1.8	1.8	2.4	0.9	2.5	1.9	1.9	1.5	1.3	0.9	0.8	0.5	
12	Ada	3	5	4	5	3	4	5	5	5	5	3	3	1	85
42	Eakly	3	5	3	5	2	3	4	3	5	5	3	2	5	75
19*	Woodward	3	5	2	5	4	1	5	3	5	5	3	1	2	70
2	Woodward	3	5	1	5	3	3	3	3	5	5	3	3	1	69
15	Durant and Calera	3	2	2	5	1	5	3	2	5	5	3	1	2	66
30*	Enid	3	5	1	5	4	1	3	2	5	5	5	3	1	65
4	Weatherford	2	5	3	5	5	1	2	3	5	5	2	1	3	65
28*	Kingfisher and Hennessey	4	5	5	1	2	1	3	4	5	1	3	1	4	59
6	Marlow	1	5	1	5	5	1	2	2	5	3	2	1	3	55
8	Norman	1	5	3	1	4	3	4	2	3	1	3	3	1	53
31*	Cherokee	3	5	1	1	2	2	1	2	5	3	4	3	5	51
21*	Elk City	2	5	1	1	1	1	2	3	5	1	3	1	2	43
9	Shawnee and Seminole	4	1	1	1	1	4	4	2	1	1	3	1	2	43

Note: sites 27 and 40 were not evaluated due to legal water availability constraints
** denotes alluvial aquifer*

Recommended and Alternate Aquifer Recharge Sites



Recharge Region 19 is located near the Town of Woodward, with the North Canadian River providing a water source and the North Canadian alluvial aquifer providing storage. The hydrogeologic characteristics of this site are very favorable for a recharge project, and this region is the only alluvial site of the three recommended sites, allowing for use of spreading basins instead of injection wells. Woodward provides an appropriate level of demand for a pilot project. In a representative low-precipitation year, there was approximately 90,000 AF at a downstream gage. Supply for a pilot project scale (maximum of 1,000 AF) is most likely available, but could be tempered by Canton Reservoir's yield requirement. Native groundwater quality is good, but source water quality has exceeded MCL for several parameters in the past.

The workgroup suggested that the high TDS levels in the source water were isolated events from nearby oil and gas operations and water source quality may be better than the annual analysis indicated, especially during the high flow times of year when a recharge project would be operating. TDS measurements were examined on a monthly basis and showed that TDS levels decrease in the higher flow months, but still exceed the MCL in those months. Almost none of the TDS measurements for the site were below the MCL. The source water quality data thus indicate pre-treatment would be required before recharging the aquifer. A pipeline approximately two miles long would be required to bring water from the North Canadian River to the recharge location.

Alternative Recharge Region 15 is located near the Town of Durant, with the Blue River providing a water source and the Antlers aquifer providing storage. The Blue River appears to provide adequate source, although the nearest gage is located approximately eight miles downstream of the probable diversion location for a project. There are several tributary streams that enter the Blue River between the probable point of diversion and the downstream gage, but the majority of the basin lies upstream of that point, suggesting that flows associated with those tributaries likely do not have a large impact on the river. The representative low-precipitation year had flows greater than 120,000 AF, suggesting there is plentiful water for a project. Water quality data for both source and groundwater are generally good, although the geochemistry was unable to be effectively compared due to a lack of hardness data. One of the largest obstacles to this project is the proposed location and lack of infrastructure. There are no existing high-capacity wells in the vicinity of the proposed location, and the area is approximately two miles from both the Blue River and Durant. Thus, this location will require installation of aquifer storage and recovery (ASR) wells and construction of transfer pipelines.

Alternative Recharge Region 30 is located near the Town of Enid, with Skeleton Creek providing a water source and the Enid Isolated Terrace aquifer providing storage. The hydrogeologic characteristics of this site are very favorable for a recharge project, with injection wells nearby or the potential to use spreading basins instead of injection wells. The nearest gage is 7 miles downstream, and annual flow during the representative low-flow year was only approximately 16,000 AF. There may be issues with supplying adequate water to the project during low-flow seasons. No surface water quality data was available for Skeleton Creek, suggesting that a monitoring program should be implemented prior to selection of the area for a project. Groundwater quality was relatively good, with few MCL exceedences. Skeleton Creek is located greater than two miles from the potential project location, but gravity flow ditches may be usable for water delivery, and the presence of nearby wells and potential for spreading basin use may lower project costs.

Statewide Water Conveyance System

The *1980 OCWP* presented a proposed Statewide Water Conveyance System as a means of assuring the entire state adequate amounts of water through 2040. The major thrust of the of the *1980 OCWP* was to meet Oklahoma's future demands through regional development and provide additional water to Oklahoma's water deficient areas by transferring surplus water from east to west. This ambitious transfer project was to be accomplished through the construction of separate northern and southern water conveyance systems. However, while the eastern leg (from southeast to central Oklahoma) of the Southern Water Conveyance System (SWCS) was shown to be potentially feasible, the western leg (from central to southwest Oklahoma) of the SWCS and the entire Northern Water Conveyance System (NWCS) proved not be economically justified under federal guidelines. Participation of the federal government in helping to fund components of this immense project would be critical to implementation.

Since publication of the *1980 OCWP*, and especially during the *2012 OCWP Update* public input process, substantial interest in the concept of a statewide water conveyance system has been revived. Consequently, the *2012 OCWP Update* revisited the feasibility of the Statewide Water Conveyance System and evaluated other alternatives as relates to today's technology and costs. The details of the updated analysis can be found in the OCWP *Water Conveyance Study*, available on the OWRB website.

In addition to the original conveyance plans included in the *1980 OCWP* (SWCS and NWCS), preliminary alternatives addressed included: (1) conveyance of water from Lake Texoma to southwestern Oklahoma as an alternative to the SWCS described in the *1980 OCWP*, (2) extension of the Lake Texoma conveyance system north as an alternative to the NWCS included in the *1980 OCWP*, (3) extension of the NWCS south from Eufaula as an alternative to the SWCS in the *1980 OCWP*, and (4) conveyance of water to north central and northwestern Oklahoma from Kaw Lake as an alternative to the NWCS in the *1980 OCWP*.

The starting point for the re-evaluation of the conveyance strategy was to identify the engineering and cost parameters used to derive the conveyance systems detailed in the *1980 OCWP*. Using these design parameters, current costs were derived for individual elements of the conveyance system (pumping stations, canals, siphons, pipelines, diversion dams and reservoirs) using two methods. The first method utilized the USACE Civil Works Construction Cost Index System (CWCCIS) to escalate the *1980 OCWP* costs to current costs based on historical cost indexes for different categories of civil engineering work. This involved applying an appropriate cost index to the cost for individual system elements. The second method (RS Means) used a current cost-estimating manual to derive costs from limited information, using unit costs for individual work tasks associated with each individual system element. For illustrative purposes, the accompanying tables show the updated costs for the 1980 Statewide Water Conveyance System using the lower of the two estimates (CWCCIS method).

Updated Construction Costs (CWCCIS Method)

Reservoir Scenario	Northern System (1980 OCWP)	Southern System (1980 OCWP)
With Flood & Chloride Control	$13.4 billion	N/A
Without Flood & With Chloride Control	$13.1 billion	N/A
With Flood & Without Chloride Control	$14.2 billion	N/A
Without Flood & Chloride Control	$13.9 billion	$5.2 billion

Updated Annual Operation, Maintenance & Replacement (CWCCIS Method)

Reservoir Scenario	Northern System (1980 OCWP)	Southern System (1980 OCWP)
With Flood & Chloride Control	$548,400	N/A
Without Flood & With Chloride Control	$548,400	N/A
With Flood & Without Chloride Control	$549,400	N/A
Without Flood & Chloride Control	$549,300	$159,600

The projects were still considered highly infeasible under both cost methods based upon cost and forecasted need. Furthermore, OCWP supply and demand analyses did not demonstrate the necessity for a large-scale statewide conveyance system. However, based upon the Watershed Planning Region report analyses, smaller scale regional conveyance systems may be viable options for eliminating projected water shortages and should be investigated. Such evaluations could include a review of the results found in the OCWP *Reservoir Viability Study* and consider smaller reservoirs as well.

Hot Spot Evaluation

As indicated in the Water Availability section and as documented in the OCWP Watershed Planning Region reports, many of the 82 OCWP basins are projected to experience surface water gaps and/or groundwater depletions. Some of these water supply shortages are relatively minor as indicated by the magnitude of the shortages and the probability of occurrences. Others are much more severe and may require more immediate attention in order to mitigate large and recurring water deficiencies. OCWP analysis included a ranking of the basins in order to determine the relative significance of water supply issues statewide. The 12 basins with the most significant water supply challenges, referred to as "hot spots," were selected for further analyses. This section summarizes the methodology and results of the hot spot identification process as well as potential solutions. Additional details of these analyses can be found in the *OCWP Water Supply Hot Spot Report*.

Hot Spot Identification Methodology

The criteria used to identify hot spots were developed based on quantitative metrics to provide an objective methodology. These analyses were based on data presented in the OCWP Watershed Planning Region reports. For initial identification, hot spots were evaluated independently for Oklahoma's three major categories of supply—surface water, alluvial groundwater, and bedrock groundwater. The hot spot analyses were based on 2060 demand, representing the most significant issues anticipated in the 50-year OCWP planning horizon.

Surface Water

Surface water supplies from reservoirs and available streamflow are major supply sources for many of the 82 OCWP basins. Impacts of current water use and projected change in demand from 2010 to 2060 were evaluated for physical supply availability, permit availability, and water quality criteria.

Surface water supply availability for each basin was calculated based on historic streamflow, unused storage in existing reservoirs, and future demand. Water supply availability results quantify how large a surface water gap will be (magnitude) and how often a gap is expected to occur (probability). As can be expected, the most significant physical supply issues are gaps that are large in magnitude and occur frequently. Thus, physical water supply criteria were developed to incorporate both the magnitude and probability of gaps for each basin.

The magnitude of a gap is represented by the likely size of a gap (median gap of all months with gaps) based on monthly analyses of the 58-year streamflow period of record (Water Years 1950 to 2007). The evaluation also assesses the severity of the gap in the basin by dividing the size of the gap by total 2060 demand in the basin. This approach provides a common basis of analysis for large and small basins alike. The probability of a gap occurring in at least one month of the year, expressed as a percent, was used to indicate the likelihood of gaps. These criteria were used to calculate a "physical supply availability index," which was converted to a score for each basin.

For the OCWP water availability analysis, surface water "permit availability" pertains to the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law. The availability of new permits is based on the Oklahoma Water Resources Board's (OWRB) analysis of annual streamflow data. Therefore, permit availability is generally correlated with the physical availability results, but some differences do occur (such as subtracting out amounts of flow already appropriated or used for domestic purposes). An analysis of permit availability for each basin is documented in the *Water Supply Permit Availability Report* on the OWRB website. The results of those analyses were used to rank the 82 basins. Basins that are already over-appropriated were considered to have the most severe permitting constraints.

The impact of water quality on the use of a supply source is driven by numerous factors, including the specific constituents of concern to a given demand sector and the economic viability of treating the water to meet the end users' water quality requirements. For the purpose of this analysis, OWRB staff developed a surface water quality condition index for streams and reservoirs to be used for assessing the relative level of water quality issues prevalent in each basin. This analysis was conducted to assist in the delineation of basins as potential "hot spots," but should not be considered an absolute characterization of basins or specific water bodies. The method for determining a water quality condition score was similar for streams and lakes. Both a trend and standards index score were calculated using water quality data primarily from the OWRB Beneficial Use Monitoring Program and recent trending analyses for both water body types. The trend and standard index scores were combined to determine a water quality condition score. The trend and standard index scores are weighted equally (50%/ 50%) to get a composite score that is ranked to determine the relative water quality condition score.

Groundwater

Groundwater in Oklahoma plays a key role in meeting water demand in basins where surface water is not readily accessible or groundwater supplies are more economical to develop. Permit availability for groundwater sources was evaluated in the *Water Supply Permit Availability Report*, but those analyses concluded that the use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits for any of the 82 basins through 2060. Therefore, basins cannot be distinguished on the basis of permit availability.

The water quality of Oklahoma's aquifers can be highly variable. Unlike surface water, there is no statewide water quality data collection program or database of water quality for groundwater. Additionally, groundwater quality can vary greatly from well to well within the same aquifer. There are known constraints for public water providers in the Blaine aquifer and Arbuckle-Timbered Hills; however, these aquifers are still used for agricultural or industrial uses. Although groundwater quality can be a significant factor in water supply analyses, the lack of an adequate groundwater quality database precluded the use of groundwater quality as a criterion for this statewide evaluation.

Consequently, the groundwater criteria focus exclusively on physical supply availability. In the OCWP Basin Reports, the availability of physical groundwater supplies were evaluated separately for bedrock aquifers and alluvial aquifers based on differences in how recharge was represented. Alluvial aquifer recharge was based on the basin's streamflow (58-year period of record), while bedrock aquifer recharge was based on average annual recharge estimates. Storage depletions occur when demand exceeds recharge. Separate criteria were developed for alluvial and bedrock groundwater.

Physical alluvial groundwater availability was determined using two components representing the severity of groundwater depletions and the rate of depletions relative to the amount of water in storage in each basin. As with surface water gaps, frequently-occurring large alluvial groundwater depletions are of more concern than infrequent or smaller depletions. Alluvial groundwater supplies are subject to hydrologic cycles of wet and drought periods, thus the occurrence and size of depletions will vary from year to year.

Two components were analyzed to assess alluvial groundwater supply availability. The first component is an assessment of the rate of depletion occurring in 2060 relative to available supplies, which indicates the severity of alluvial groundwater depletions relative to the amount of water in storage. The second component of the physical alluvial groundwater availability score was derived from using only the size and probability of alluvial groundwater depletions; storage was not considered in this rating. This component symbolizes the magnitude of the alluvial storage depletion in the basin. These two components were combined to develop an alluvial groundwater physical availability ranking for each basin.

The physical availability of bedrock groundwater was scored using a similar method. However, as bedrock groundwater supplies are much less hydrologically-dependent on streamflow and recharged at more constant rates, the probability of bedrock storage depletions is not applicable. In a given future year, bedrock groundwater depletions either will or will not occur, based on whether the demand exceeds the relatively-constant rate of recharge in that year.

As with alluvial groundwater, two components were used to determine a physical availability score for bedrock groundwater. The first component relates the median annual depletion to the amount of bedrock groundwater storage in a basin, excluding minor aquifers, again representing the severity of the rate of depletion relative to available supplies. The second component ranks each basin's median annual depletion of bedrock groundwater supplies in comparison to bedrock groundwater depletions in other basins. These two components were used to develop a physical bedrock groundwater availability ranking for each basin.

Results of Hot Spot Identification

An overall hot spot ranking was developed for surface water and groundwater availability of each basin. For surface water, the physical supply availability, permit availability, and water quality results were combined to determine an overall score and ranking for the basins. As discussed, alluvial and bedrock groundwater hot spot rankings were based solely on physical supply availability analyses.

In order to determine the overall scores and rankings for the basins, a weighting of each of the criteria was needed. The following weights were assigned for surface water:

- Physical Supply Availability = 50%
- Water Quality = 20%
- Permit Availability = 30%

The heavier weighting on physical supply availability reflects the critical nature of having a physical supply shortage. Permit availability, while critical for utilizing a surface water supply, was weighted slightly lower because permit availability is dependent on surface water availability. Water quality is also highly important in meeting the needs of various water users, but was viewed as less critical than the physical and permitting criteria because treatment technologies can be applied in many situations to resolve differences between raw water quality and the users' water quality requirements.

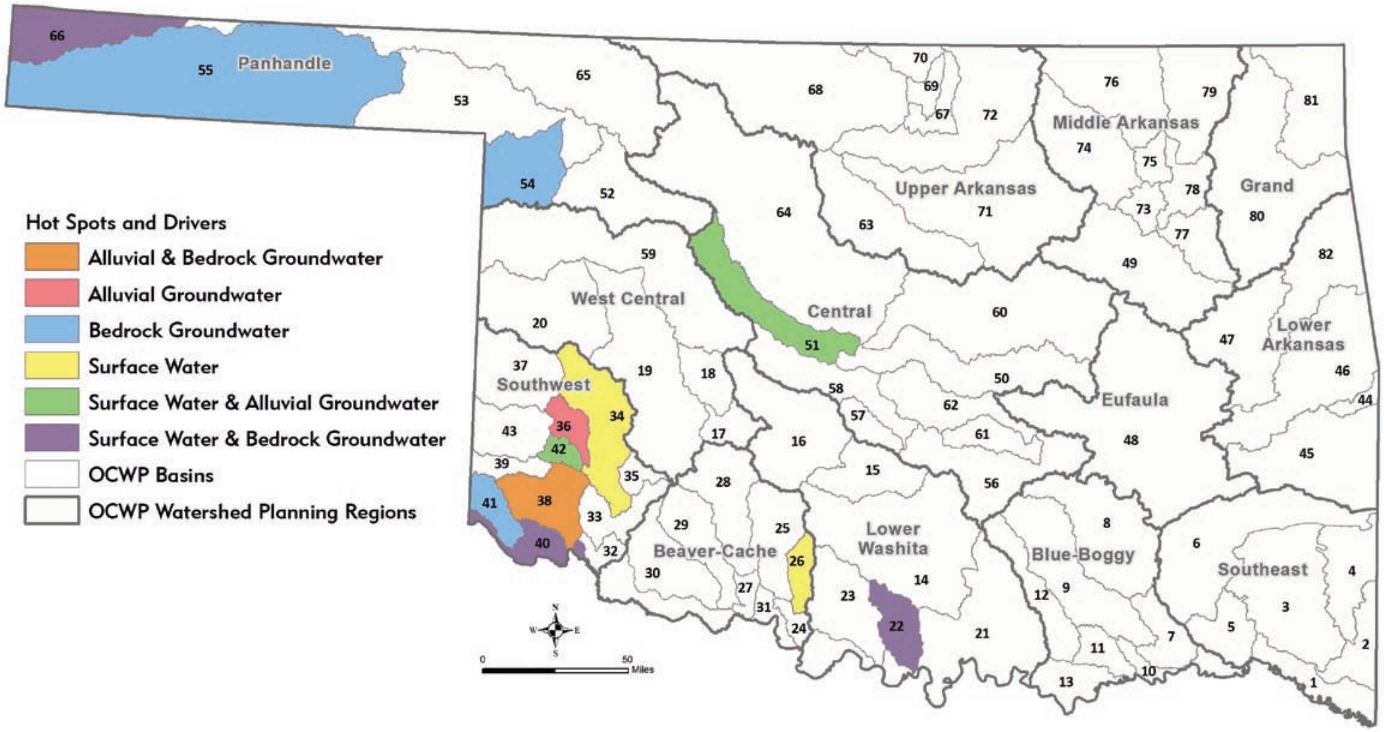
The same approach was taken to develop a composite score for alluvial and bedrock groundwater for each of the 82 basins, but solely based on physical supply availability as discussed. The weighting for the two components used to rate alluvial groundwater and the two components used to rate bedrock groundwater were combined with equal weighting (50%/50%).

Based on the ranking of basins for surface water hot spots, alluvial groundwater hot spots, and bedrock groundwater hot spots, a total of 12 basins were selected for more detailed analysis regarding the cause of the supply issues and more detailed investigations regarding potential water supply solutions for those basins. The 12 basins, include the top seven ranked surface water supply hot spot basins, the top four ranked alluvial groundwater supply hot spot basins, and the top six ranked bedrock groundwater supply hot spots. Because some basins are among the top hot spots in more than one supply source category (such as Basin 22, which was rated as a hot spot for both surface water and bedrock groundwater), the combined total number of basins is 12.

Potential Supply Options for the Hot Spot Basins

Six basic options were evaluated to assess their effectiveness in mitigating water supply challenges for each hot spot: demand management, use of out-of-basin supplies, reservoir use, increasing reliance on surface water, increasing reliance on groundwater (which also includes opportunities for artificial recharge), and use of marginal quality water. The water supply options are considered separately (only one option at a time) in order to highlight the effectiveness of each option. All of the options and resources are discussed in more detail in the Water Supply Options section of this report.

Hot Spot Basins



Drivers for Hot Spot Basins

Region	Basin #	Major Drivers
Lower Washita	22	Hot spot for surface water and bedrock groundwater. The surface water hot spot is driven by physical availability (ranked #1). Bedrock groundwater storage depletions are ranked #10 for both overall size and portion of major aquifer storage depleted.
Beaver-Cache	26	Surface water hot spot. The hot spot is driven by physical availability (ranked #5) and potential water quality issues (ranked #9.)
Southwest	34	Surface water hot spot. The hot spot is driven by all three criteria: physical availability (ranked #6), permit availability (ranked #11), and potential water quality issues (ranked #5).
	36	Alluvial groundwater hot spot. The basin is the worst alluvial groundwater hot spot, where alluvial groundwater storage depletions are ranked #2 for overall size and ranked #1 for the portion of major aquifer storage depleted.
	38	Hot spot for alluvial groundwater and bedrock groundwater. Both the alluvial groundwater and bedrock groundwater storage depletions are ranked high, #3 and #5 respectively, for the portion of major aquifer storage depleted. The basin also received a high ranking, #13 and #8, respectively, for the size of alluvial groundwater and bedrock groundwater storage depletions.
	40	Hot spot for surface water and bedrock groundwater. The surface water hot spot is driven by moderately high rankings in all three criteria: physical availability (ranked #17), permit availability (ranked #18), and potential water quality issues (ranked #16). Bedrock groundwater hot spot storage depletions have high rankings for both criteria; ranked #6 for overall size and ranked #11 for the portion of major aquifer storage depleted.
	41	Bedrock groundwater hot spot. The basin is the second worst bedrock groundwater hot spot, where storage depletions are ranked #4 for overall size and ranked #7 for the portion of major aquifer storage depleted.
	42	Hot spot for surface water and alluvial groundwater. The surface water hot spot is driven by physical availability (ranked #7) and has a moderately high ranking for potential water quality issues (ranked #19). The basin is the second worst alluvial groundwater hot spot, where storage depletions are ranked #1 for overall size and ranked #3 for the portion of major aquifer storage depleted.
Central	51	Hot spot for surface water and alluvial groundwater. The basin is the worst surface water hot spot and the third worst alluvial groundwater hot spot. The surface water hot spot is driven by physical availability (ranked #6) and permit availability (ranked #1). The basin is the third worse alluvial groundwater hot spot, where storage depletions are ranked #6 for overall size and ranked #2 for the portion of major aquifer storage depleted.
Panhandle	54	Bedrock groundwater hot spot. The basin is the worst bedrock groundwater hot spot, where storage depletions are ranked #8 for overall size and ranked #2 for the portion of major aquifer storage depleted.
	55	Bedrock groundwater hot spot. The basin is the fifth worst bedrock groundwater hot spot, where storage depletions are ranked #12 for overall size and ranked #1 for the portion of major aquifer storage depleted.
	66	Hot spot for surface water and bedrock groundwater. The surface water hot spot is driven by physical availability (ranked #12) and permit availability (ranked #9). The basin is the third worst bedrock groundwater hot spot, where storage depletions are ranked #7 for overall size and ranked #4 for the portion of major aquifer storage depleted.

Basin 22

Basin 22, located in the Lower Washita Watershed Planning Region, is a surface water and bedrock groundwater hot spot. Surface water issues are mainly due to the basin's low physical availability of streamflow; the availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Storage depletions are expected to provide water supply challenges based on the overall size of the depletions and for the rate of storage depletions relative to the amount of storage in the Antlers bedrock aquifer. More detailed information on this basin is available in the *Lower Washita Watershed Planning Region Report*. In addition to surface water gaps and bedrock groundwater storage depletions, alluvial groundwater storage depletions may occur by 2050. Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 22 are summarized in the accompanying table and text.

Demand Management

For Basin 22, Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand by 820 acre-feet per year (AFY) and reduce the size of the annual 2060 surface water gaps by about 44% to a value of 460 AFY, alluvial groundwater storage depletions by about 25% to a value of 90 AFY, and bedrock groundwater depletions by about 18% to a value of 770 AFY. These conservation measures could benefit users throughout the basin and should be considered as a short- to long-term water supply option.

Scenario II (substantially expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand by 1,970 AFY. These additional conservation measures could reduce the size of the 2060 annual surface water gaps by 72% to a value of 230 AFY, alluvial groundwater storage depletions by 67% to a value of 40 AFY, and bedrock groundwater depletions by 45% to a value of 520 AFY. These substantially expanded conservation measures could further benefit users throughout the basin and should be considered as a long-term water supply option.

Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options for Basin 22, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

Lake Texoma, which is approximately 40 miles from the center of Basin 22, has substantial unpermitted yield to meet the needs of new users. However, the water would likely require treatment for M&I use due to total dissolved solids (TDS) concentrations.

The OCWP *Reservoir Viability Study* identified 11 Category 4 and Category 3 potential out-of-basin reservoir sites in the Lower Washita Watershed Planning Region. Potential Category

OCWP Conservation Scenarios

Demand Sector	Conservation Scenario	Description
Municipal & Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for Public-Supplied Residential Sector and 2030 for Public-Supplied Nonresidential Sector. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90% of water providers in each county will meter their customers. • Non-revenue water loss will be reduced to 12%, where applicable. • Conservation pricing will be implemented by 20% of purveyors in rural counties, 40% in mostly urban counties, and 60% in counties with high metropolitan populations. • Water conservation educational programs (including billing inserts and conservation tip websites) will be implemented by all providers, estimated to reduce demand by 3%.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I) • All purveyors will meter their customers. • Non-revenue water loss will be reduced to 10% where applicable. • Conservation pricing will be implemented by 60% of purveyors in rural counties, 80% in mostly urban counties, and 100% in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5% including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80% beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42). • In Harmon, Jackson, Tillman, and Kiowa counties, 10% of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42). • All sprinkler systems will have a field application efficiency of 90% beginning in 2015, representing implementation of Low Energy Precision Application nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what if" scenario.

Supply Options for Basin 22

Basin 22	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency • Significantly expanded M&I conservation measures and shift to crops with lower water demand	Short- to long-term solution that may reduce approximately 70% of surface water gaps and alluvial groundwater storage depletions, and up to 45% of bedrock groundwater storage depletions
Out-of-Basin Supplies	• Potential Caddo Creek, Courtney, Durwood, and Ravia reservoirs • Supply from Lake Texoma • Statewide water conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs and/or reallocation of storage	May provide long-term solution; additional analysis required.
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on the Antlers bedrock aquifer instead of increased surface water and alluvial groundwater use	May provide long-term solution; localized adverse impacts may occur
Marginal Quality Water Use	• Use of marginal water quality sources	No significant sources identified; site-specific potential for reuse of oil and gas flowback and produced water for oil and gas drilling and operations

4 out-of-basin supplies within a 35-mile radius of Basin 22 include Caddo Creek Reservoir (40,000 AFY yield), Courtney Reservoir (53,000 AFY yield) Durwood Reservoir (232,000 AFY yield), and Ravia Reservoir (25,300 AFY yield). The Caddo Creek and Courtney Reservoir sites are approximately 14 miles from the center of Basin 22, and the Durwood and Ravia Reservoir sites are approximately 30 and 34 miles respectively from the center of Basin 22. With new terminal storage of about 1,200 acre-feet (AF), a 14-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 22 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 24-inch diameter pipeline would be needed. Each of these potential sites provide much more water than needed for Basin 22, and thus might provide opportunities for regional water supply projects.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 22. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

Additional reservoir storage in Basin 22 can effectively supplement supply during dry months. The entire increase in water demand from 2010 to 2060 could be supplied by a new reservoir diversion and 5,800 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

There are currently more than 10 existing NRCS reservoirs in Basin 22, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to meet some agricultural demands, but could be evaluated to determine the potential for rehabilitation or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the potential volume of storage in the basin, further investigation of these water supplies may be merited.

The OCWP *Reservoir Viability Study* identified Burneyville Reservoir as a potential Category 3 reservoir site in Basin 22. This reservoir is expected to provide 25,000 AFY of dependable yield with a total conservation storage of 119,000 AF. This water supply yield is substantially greater than the amount required by Basin 22; therefore, the new reservoir may be able to provide out-of-basin supplies for nearby basins or serve as a regional supply. Additional analyses would be required to determine the feasibility of this project.

Increasing Reliance on Surface Water

Use of surface water to meet local demand in Basin 22 through 2060 is not expected to be limited by the availability of permits. However, there is a very high probability of physical surface water gaps starting in 2020 for the baseline demand projections. Increasing reliance on surface water use without reservoir storage would increase the size and probability of these gaps. Therefore, increasing reliance on surface water supplies without reservoir storage in Basin 22 is not recommended.

Increasing Reliance on Groundwater

Bedrock groundwater supplies, mainly from the Antlers bedrock aquifer, are used to meet 52% of the demand in Basin 22. The Antlers aquifer underlies most of the southern half of the basin and has substantial groundwater storage in the basin. The projected growth in surface water and alluvial groundwater use could instead be supplied by the Antlers bedrock aquifer, but would result in small (1,270 AFY) increases in projected bedrock groundwater storage

NRCS Reservoirs in Basin 22

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	3	126
>50 AF	10	2,508
Largest Reservoir (AF)	N/A	999

depletions. While increasing use of bedrock water would not substantially increase depletions compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water and alluvial groundwater could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

The majority of current alluvial groundwater rights are in non-delineated minor aquifers; therefore, the typical yields, volume of stored water, and water quality are unknown. Increasing reliance on these supplies is not recommended without site-specific information.

Use of Marginal Quality Water

Basin 22 was not found to have significant sources of marginal quality water (MQW) or significant potential to offset demand with MQW. The Oil and Gas demand sector could potentially use MQW from oil and gas flowback or produced water for drilling and operational activities. Opportunities to reuse flowback or produced water should be considered on an individual well field basis for cost-effectiveness relative to other available supplies.

Basin 26

Basin 26 is a surface water hot spot, where surface water issues are mainly associated with the basin's low physical availability of streamflow and poor water quality. The availability of new permits is not expected to limit the development of surface water for in-basin use through 2060. More detailed information on this basin is available in the *OCWP Beaver-Cache Watershed Planning Region Report*. Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 26 are summarized in the accompanying table and text.

Demand Management

For Basin 26, Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 26 by 410 AFY, reducing the size of the 2060 annual surface water gaps by up to 90% to a value of 10 AFY and bedrock groundwater storage depletions by about 17% to a value of 250 AFY. Moderately expanded conservation measures could benefit users throughout the basin and should be considered as a short– to long-term water supply option.

Scenario II (substantially expanded) irrigation and M&I conservation measures could decrease the total associated 2060 demand in Basin 26 by 790 AFY, eliminating the 2060 annual surface gap and reducing the size of the 2060 bedrock groundwater storage depletions by 53% to a value of 140 AFY. These measures could benefit users throughout the basin and should be considered as a long-term water supply option.

Supply Options for Basin 26

Basin 26	Option	Feasibility
Demand Management	• Moderately expanded conservation for M&I sector and increased Crop Irrigation efficiency • Substantially expanded M&I and irrigation conservation	Short- to long-term solution that may eliminate surface water gaps and reduce bedrock groundwater storage depletions by 53%
Out-of-Basin Supplies	• Waurika Lake • Cookietown Reservoir • Statewide water conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs and/or reallocation of storage	Small impoundments may be feasible for long-term solutions
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on the non-delineated minor groundwater sources currently used	Not feasible
Marginal Quality Water Use	• Use of marginal water quality sources	No significant sources identified

Out-of-Basin Supplies

Out-of-basin supplies from Waurika Lake through the Waurika Lake Master Conservancy District (Waurika MCD) are a major source of supply for Basin 26, where the cities of Duncan and Comanche received more than 5,000 AFY in 2007. Increasing reliance on Waurika, assuming existing infrastructure is adequate or, if needed, construction of new infrastructure, could mitigate surface water gaps. However, Waurika Lake is fully allocated to the Waurika MCD, thus existing users and allocation of the lake's supplies would need to be considered. If suitable supplies could be allocated from the Waurika MCD, an additional 180 AFY of out-of-basin supplies from Waurika Lake, which is approximately 10 miles away from the center of the basin, could meet the M&I demand in Basin 26. A 6 inch diameter pipe would be needed to bring out-of-basin supplies into Basin 26 for further distribution to users.

The construction of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potential reservoir sites within the Beaver-Cache Region: Snyder Lake (Category 3) and Cookietown Reservoir (Category 4). The site in nearest proximity to Basin 26 is Cookietown Reservoir, located in Basin 30. This reservoir is expected to provide 34,700 AFY of dependable yield with a total conservation storage of 208,000 AF. With new terminal storage of approximately 400 AF, an 8-inch diameter pipe would be needed to bring Cookietown Reservoir supplies at a constant flow rate into Basin 26 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 14-inch diameter pipeline would be recommended. Cookietown Reservoir could supply a much greater amount of dependable yield than required by Basin 26 ; therefore, the new reservoir may be able to provide a regional source of supply for nearby basins as well.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 26. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

Additional reservoir storage in Basin 26 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 900 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

There are currently more than 20 existing NRCS reservoirs in Basin 26, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to serve relatively minor agricultural needs, but could be evaluated to determine the potential for rehabilitation and/or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the potential volume of storage in the basin further investigation of these water supplies may be merited. No viable reservoir sites were identified in Basin 26.

Increasing Reliance on Surface Water

There is a high probability of surface water gaps in supplies from Cow Creek starting in 2020 for the baseline demand projections. Increasing reliance on surface water supplies through direct stream diversions would increase the size and probability of gaps. Surface water in the basin also has relatively poor water quality. Therefore, increasing reliance on Basin 26 surface water supplies without reservoir storage is not recommended.

NRCS Reservoirs in Basin 26

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	11	323
>50 AF	12	1,423
Largest Reservoir (AF)	N/A	377

Increasing Reliance on Groundwater

There are no major aquifers in Basin 26. The majority of groundwater rights in Basin 26 are in non-delineated minor bedrock aquifers. Increasing reliance on these supplies is not recommended on a basin-wide scale. Because of the low well yields associated with minor aquifers, these supplies are unlikely to meet the needs of large-scale users and the viability of these supplies is site-specific.

Marginal Water Quality Water Use

Basin 26 was not found to have significant marginal quality water sources or significant potential to offset demand with marginal quality water.

Basin 34

Basin 34 is a surface water hot spot. Surface water issues are mainly due to the basin's low physical availability of streamflow, lack of available streamflow for new permits, and poor water quality. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to surface water gaps, alluvial groundwater storage depletions may occur by 2020. Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 34 are summarized in the accompanying table and text.

Demand Management

Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand by 1,970 AFY and reduce the size of the annual 2060

Supply Options for Basin 34

Basin 34	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation and increase Crop Irrigation efficiency. • Substantially expanded M&I and shift to crops with lower water demand	Short- to long-term solution that may reduce about 50% of surface water gaps and 70% of alluvial groundwater storage depletions
Out-of-Basin Supplies	• Statewide water conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs and/or reallocation of storage	Potentially long-term solution; additional analyses required
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage.	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on Elk City bedrock aquifer instead of increased surface water or alluvial groundwater use. • Increased reliance on North Fork of the Red River alluvial aquifer instead of increased surface water use.	Elk City bedrock aquifer could be a short- to long-term solution
Marginal Quality Water Use	• Use of marginal water quality sources	No significant sources identified

surface water gaps by up to 35% to a value of 1,620 AFY and alluvial groundwater storage depletions by about 59% to a value of 190 AFY. This conservation measure could benefit users throughout the basin and should be considered as a short– to long-term water supply option.

Scenario II (substantially expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand by 2,720 AFY and reduce the size of annual 2060 surface water gaps by 48% to a value of 1,300 AFY and alluvial groundwater storage depletions by 72% to a value of 130 AFY. These measures could benefit users throughout the basin and should be considered as a long-term water supply option.

Out-of-Basin Supplies

The City of Elk City is the largest M&I demand in the basin and currently obtains out-of-basin water supplies from the North Fork of the Red River aquifer in Basin 37. Increasing use of this supply could be a short- to long- term water supply option for the city in the future. However, storage depletions from local demand may occur in Basin 37 by 2020 and adversely affect well yields, water quality, and/or pumping costs.

Implementation of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for alluvial groundwater depletions and surface water gaps. The development of new out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing new out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified one potential out-of-basin reservoir site in the Southwest Planning Region. The Mangum Reservoir (Lower Mangum Damsite) Category 4 site , located about 16 miles from the center of Basin 34 in Basin 39, would provide a dependable yield of 18,494 AFY from a 47,043 AF of storage. With new terminal storage of about 1,800 AF, a 14-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 34 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 30-inch diameter pipeline would be needed. The site would provide much more water than needed for Basin 34 alone, thus might be a possible consideration for a regional-type water supply source.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 34. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 4,100 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. Since surface water in the basin is fully permitted, the potential for existing water rights to supply additional storage would need to be analyzed.

There are currently 35 existing NRCS reservoirs in Basin 34, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to provide relatively minor agricultural supplies, but could be evaluated to determine the potential for rehabilitation and/or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the volume of storage in the basin, further investigation of these water supplies may be merited.

The OCWP *Reservoir Viability Study* identified Port Reservoir as a potential Category 3 reservoir site in Basin 34. This reservoir is expected to provide 9,000 AFY of dependable yield with a total conservation storage of 115,700 AF. This water supply yield is greater than the amount required by Basin 34; therefore, the new reservoir may be able to provide out-of-basin supplies for nearby basins or serve as a regional supply. However, since the basin has been fully allocated, substantial permit issues would have to be resolved to construct larger reservoirs.

Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a moderate probability of surface water gaps starting in 2020 for the baseline demand projections. Increasing reliance on surface water supplies through direct stream diversions would increase the size and probability of gaps. Surface water in the basin also has relatively poor water quality. Therefore, increasing reliance on Basin 34's surface water supplies without reservoir storage is not recommended.

Increasing Reliance on Groundwater

Alluvial groundwater supplies are used to meet about 20% of the total demand, and bedrock groundwater is used to meet 32% of the total demand, largely for the Crop Irrigation and Oil and Gas demand sectors. The North Fork of the Red River alluvial aquifer underlies the basin in the south (about 15% of the overall basin area) and the Elk City bedrock aquifer

NRCS Reservoirs in Basin 34

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	14	530
>50 AF	21	3,408
Largest Reservoir (AF)	N/A	964

underlies the basin in the north (about 15% of the overall basin area). Due to the hydraulic interconnectivity between alluvial groundwater and surface water, a shift from surface water to alluvial groundwater is not expected to substantially change the maximum storage depletions or surface water gaps in the basin. Increasing use of the Elk City bedrock aquifer, with new infrastructure, could provide short- to long-term supplies instead of increasing surface water and alluvial groundwater use, but may cause storage depletions. The resulting storage depletions of up to 710 AFY are minimal relative to the amount of storage (more than one million AF) in Basin 34's portion of the Elk City aquifer.

Use of Marginal Quality Water

Basin 34 was not found to have significant marginal quality sources or significant potential to offset demand with marginal quality water.

Basin 36

Basin 36 is an alluvial groundwater hot spot, where storage depletions are expected to provide water supply challenges based on the overall size of the depletions and for the rate of storage depletions relative to the amount of groundwater storage in the North Fork of the Red River aquifer. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to alluvial groundwater storage depletions, surface water in basin 36 is fully allocated and surface water surface water gaps may occur by 2050. Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 36 are summarized in the accompanying table and text.

Demand Management

Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total demand by 440 AFY. These expanded conservation measures would have little impact on the size of the 2060 surface water use, but could reduce the size of the 2060 alluvial groundwater storage depletions 15% to a value of 2,170 AFY. These conservation measures could benefit users throughout the basin and should be considered as a short– to long-term water supply option.

Scenario II (substantially expanded) irrigation and M&I conservation measures could reduce the total 2060 demand by 1,320 AFY. The combined demand reduction in both sectors may eliminate 2060 surface water gaps and decrease 2060 alluvial groundwater storage depletions by about 47% to a value of 1,360 AFY. This measure could benefit users throughout the basin and should be considered as a long-term water supply option. Additional conservation measures in the M&I demand sector may help reduce the adverse effects of localized storage depletions, but will not have a significant impact basin wide, because the basin's M&I demand is significantly less than that of the Crop Irrigation demand sector.

Supply Options for Basin 36

Basin 36	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency • Significantly expanded M&I conservation measures and shift to crops with lower water demand	Short- to long-term solution that could eliminate surface water gaps and reduce 2060 groundwater depletions by 15% to almost 50%
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Potential long-term solution, but limited in reservoir size; additional analysis required
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on North Fork of Red River aquifer	Long-term solution with possible localized adverse impacts
Marginal Quality Water Use	• Use brackish groundwater sources for Crop Irrigation	Potential long-term applicability for irrigation of certain crops

Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options, but could eliminate the potential for alluvial groundwater depletions and surface water gaps. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potential Category 3 or 4 sites in the Southwest Planning Region: Port Reservoir (Category 3) in Basin 34 and the Lower Mangum site (Category 4) in Basin 39. The Mangum Reservoir site was recognized as the nearest most viable site, located about 16 miles from the center of Basin 36. The potential site could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 1,800 AF, a 14-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 36 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 30-inch diameter pipeline would be needed. The estimated reservoir yield in Mangum is much greater than what is needed to supply Basin 36, thus the site might be considered for a regional water supply project.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 36. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. The Lugert-Altus Reservoir currently uses the majority of flow to supply dependable yield to its users and is not expected to provide additional supplies in the future unless supplemental water resources are found. New small reservoirs (less than 50 AF) could be developed under existing permits to mitigate surface water gaps and reduce the adverse effects of localized storage depletions. There are insufficient surface water supplies to meet the entire increase in demand from 2010 to 2060, and the construction of larger reservoirs would require that substantial permit issues be resolved. If permittable, a new river diversion and 200 AF of reservoir storage at the basin outlet could meet the increase in surface water demand; however, any new reservoirs could not impact the yield of Lugert-Altus Reservoir. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a very high probability of surface water gaps starting in 2050 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase the size and probability of these gaps. Therefore, increasing reliance on Basin 36 surface water supplies is not recommended.

Increasing Reliance on Groundwater

Alluvial groundwater storage depletions of up to 1,000 AF/month are expected to occur in the months of July and August of almost every summer by 2060. These storage depletions are small in size relative to the basin storage in the North Fork of the Red River alluvial aquifer, which underlies about 60% of the basin. Due to the relatively small projected growth in surface water use, new surface water users could instead be supplied by the North Fork of the Red River aquifer with minimal (10 AFY) increases in projected storage depletions. Due to the alluvial aquifer's connection to river flows and precipitation, aquifer levels may fluctuate naturally due to prolonged periods of drought or above-average precipitation. While increasing use of alluvial water would not substantially increase depletions water in storage, the effect of these storage depletions may be intensified during periods of drought and localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional alluvial groundwater supplies to meet the growth in surface water could be considered a long-term water supply option, but may require additional infrastructure and increasing operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

Use of Marginal Quality Water

Basin 36 was found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 milligrams per liter (mg/L) and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. The U.S. Geological Survey (USGS) is currently conducting a 3-year study (to be completed in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states. Brackish groundwater underlies the entire basin and should be evaluated as a potential short– to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Fork of the Red River aquifer.

Basin 38

Basin 38 is an alluvial groundwater and bedrock groundwater hot spot. The basin is mainly challenged by the rate of storage depletions in the Blaine and North Fork of the Red River aquifers. However, the overall size of storage depletions to these aquifers may also create significant water supply challenges. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to alluvial groundwater storage depletions, surface water gaps and bedrock groundwater storage depletions may occur by 2060; however, surface water permit availability is not projected to limit surface water use through 2060. Six categories of supply options for mitigating surface water gaps and groundwater storage depletions in Basin 38 are summarized in the accompanying table and text.

Supply Options for Basin 38

Basin 38	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency • Significantly expanded M&I conservation measures and shift to crops with lower water demand	Short- to long-term solution that could eliminate surface water gaps and reduce 2060 groundwater depletions by 15% to almost 50%
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Potential long-term solution, but limited in reservoir size; additional analysis required
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on North Fork of Red River aquifer	Long-term solution with possible localized adverse impacts
Marginal Quality Water Use	• Use brackish groundwater sources for Crop Irrigation	Potential long-term applicability for irrigation of certain crops

Demand Management

Scenario I (moderately expanded) crop irrigation conservation measures could reduce the associated 2060 total demand by 15,210 AFY, which may eliminate 2060 surface water gaps and alluvial and bedrock groundwater storage depletions. These conservation measures could benefit users throughout the basin and should be considered as a short- to long-term water supply option. Additional conservation measures in the M&I demand sector may help reduce localized storage depletions and gaps, but will not have a significant impact basin wide because the basin's M&I demand is significantly less than that of the Crop Irrigation demand sector.

Scenario II (substantially expanded) irrigation and M&I conservation measures are not necessary to eliminate gaps and storage depletions.

Out-of-Basin Supplies

There are substantial existing out-of-basin supplies from the Lugert-Altus Irrigation District, however, the District is not expected to provide supplies for new irrigators in the future unless additional sources of supply are secured. The City of Altus also receives an out-of-basin supply from the Lugert-Altus Irrigation District and the Mountain Park Master Conservancy District in Basin 35, and the City of Mangum obtains out-of-basin supplies from the North Fork of the Red River aquifer in Basin 36.

New out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The construction of new out-of-basin reservoir supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potentially viable sites in the Southwest Region: Mangum Lower Dam Site (Category 4) in Basin 39 and Port Reservoir (Category 3) located in Basin 34. Mangum Reservoir was recognized as the nearest most viable site, located about 11 miles from the center of Basin 38. The potential site could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 7,000 AF, a 30-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 38 for further distribution to users and eliminate gaps and storage depletions. With no terminal storage and variable flows in the pipeline, a 54-inch diameter pipeline would be needed. The estimated yield of the Mangum Reservoir site is much higher than needed to meet Basin 38's long-term needs, thus this site might be considered for a regional water supply project.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 38. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

Reservoir storage could provide dependable supplies to mitigate surface water gaps and adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 8,900 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. However, a detailed evaluation of the feasibility of any reservoir would be needed and should include consideration of existing land ownership, costs, geology, water quality, and permitting compact obligations. The OCWP *Reservoir Viability Study* did not identify any large viable sites in Basin 38.

There are currently more than 25 NRCS reservoirs in Basin 38, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to provide water for relatively small agricultural uses, but could be evaluated to determine the potential for rehabilitation and/or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the potential volume of storage in the basin, further investigation of these water supplies may be merited.

Increasing Reliance on Surface Water

The primary sources of water (62% of the total demand) in this basin are surface water and out-of-basin supplies from the Lugert-Altus Irrigation District, which is not expected to provide supplies for new irrigators in the future unless additional water supplies can be secured. Therefore, additional water supplies will be needed from the Salt Fork of the Red River or from alluvial or bedrock aquifers. Unlike many basins in the Southwest Region, use of surface water to meet local demand in Basin 38 through 2060 is not expected to be limited by the availability of permits. However, there is a low to moderate probability of surface water gaps starting in 2020 for the baseline demand projections. Increasing reliance on surface water use would increase the size and probability of these gaps. Therefore, increasing reliance on Basin 38 surface water supplies without reservoir storage is not recommended.

NRCS Reservoirs in Basin 38

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	5	226
>50 AF	23	2,846
Largest Reservoir (AF)	N/A	640

Increasing Reliance on Groundwater

Currently, about 25% of the total demand is met from the Blaine aquifer, primarily for Crop Irrigation due to water quality constraints, and about 13% is met from non-delineated minor aquifers along the Salt Fork of the Red River and Turkey Creek. Under baseline demand conditions, storage depletions in alluvial and bedrock aquifers are expected to increase due largely to the growth in Crop Irrigation demand, which may cause adverse effects in localized areas. The projected growth in surface water and alluvial groundwater use for irrigation purposes could alternatively be supplied by the Blaine bedrock aquifer in the western half of the basin, but would result in large (6,900 AFY) increases in projected bedrock groundwater storage depletions. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. The impacts may be intensified by the geology of the aquifer; water may be obtained from cavities, solution channels, and fractures in the rock, where depletions could create changes in these features that may intensify the effect of storage depletions on a local level.

Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water could be considered a long-term water supply option, but may require additional infrastructure and increasing operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

Artificial recharge has been conducted in the Blaine aquifer since the late 1960s. In 1997, a groundwater recharge study was performed by the OWRB to determine the effectiveness of artificial recharge wells in Basins 40 and 41. The study found that on average, one recharge well could recharge the aquifer at a rate of about half that of the water withdrawal from an irrigation well (recharge of 70 AFY compared to average annual pumping of 142 AFY per irrigation well). Increasing use of this practice could be effective at reducing the effects of localized storage depletions in Basin 38.

The majority of current alluvial groundwater rights are in non-delineated minor aquifers; therefore, the typical yields, volume of stored water, and water quality are unknown. Increasing reliance on these supplies is not recommended without site-specific information.

Use of Marginal Quality Water

Basin 38 was found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers, such as the Blaine aquifer. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. The USGS is currently conducting a 3-year study scheduled for completion in 2012 to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states. Brackish groundwater underlies the entire basin and should be evaluated as a potential short– to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Fork of the Red River aquifer. Implementation of the chloride control project on the Elm Fork of the Red River in Basins 42 and 43 could be a viable option for increasing surface water supplies.

Basins 40 & 41

Basins 40 and 41 represent the entire watershed of Sand Creek in Oklahoma and have very similar water supply needs and resources; therefore, they were evaluated as a single hot spot. Basin 40 is a surface water and bedrock groundwater hot spot, and Basin 41 is a bedrock groundwater hot spot. Surface water issues are mainly due to low physical availability of streamflow, lack of available streamflow for new permits, and relatively poor water quality. Both basins are challenged by the overall size of storage depletions and for the rate of storage depletions relative to the amount of groundwater storage in the Blaine aquifer. Shortages in these basins are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*.

In addition to the challenges noted, surface water gaps may occur in Basin 41 by 2030 and alluvial groundwater storage depletions may occur by 2020 in both Basin 40 and Basin 41. Six categories of supply options for mitigating surface water gaps and groundwater storage depletions in Basins 40 and 41 are summarized in the accompanying table and text.

Supply Options for Basins 40 & 41

Basins 40 & 41	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency	Short- to long-term solution that may reduce surface water gaps in Basin 40 by 73%, alluvial groundwater storage depletions by about 90%, and eliminate bedrock storage depletions All gaps and storage depletions could be eliminated in Basin 41
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Potential long-term solution, but limited in reservoir size; additional analysis required
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on the Blaine bedrock aquifer	Long-term solution with possible localized adverse impacts
Marginal Quality Water Use	• Use brackish groundwater sources for Crop Irrigation	Potential long-term applicability for irrigation of certain crops

Demand Management

Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the associated 2060 demand in Basin 40 by 3,600 AFY, which could reduce the 2060 surface water gap by 73% to a value of 70 AFY, reduce the 2060 alluvial groundwater storage depletions by 90% to a value of 80 AFY, and eliminate bedrock groundwater storage depletions. In Basin 41, Scenario I conservation measures could reduce associated 2060 demand by 5,220 AFY, which could eliminate all of the 2060 surface water gaps and groundwater storage depletions. These conservation measures could benefit users throughout the basins and should be considered as a short– to long-term water supply option. However, while additional conservation measures in the M&I demand sector may help reduce the adverse effects of localized storage depletions, these measures will not have a significant impact basin wide, because the basins' M&I demand is significantly less than that of the Crop Irrigation demand sector.

Scenario II (substantially expanded) irrigation and M&I conservation measures are not expected to provide substantial additional reductions in gaps and storage depletions in Basin 40 and are not necessary in Basin 41.

Out-of-Basin Supplies

Gould Public Works Authority (PWA), which is located in Basin 41, currently has an existing permit to transfer water from out-of-basin sources in Basin 39. Substantial increases in out-of-basin supplies from this basin are not expected, since all surface water in Basin 39 is fully allocated and the basin has a moderate annual probability of surface water gaps.

Construction of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The construction of new out-of-basin reservoir supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potentially viable sites in the Southwest Region: Mangum Lower Dam Site (Category 4) in Basin 39 and Port Reservoir (Category 3) in Basin 34. Mangum Reservoir is located about 25 miles from the center of Basins 40 and 41 and could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 4,000 AF, a 20-inch diameter pipe would be needed to bring out-of-basin supplies at a constant rate into Basins 40 and 41 for further distribution to users and eliminate gaps and storage depletions. With no terminal storage and variable flows in the pipeline, a 42-inch diameter pipeline would be needed. Since the estimated yield of Mangum Reservoir is greater than needed to supply both basins' demand, this site could be considered for a regional water supply project.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basins 40 and 41. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

New small reservoirs (less than 50 AF) could be potentially effective to reduce surface water gaps or adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, Basin 40's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 5,600 AF of reservoir storage at the basin outlet and Basin 41's by a new river diversion and 12,600 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basins or reservoirs upstream of the basins' outlets may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

Surface water in these basins is fully allocated, limiting diversions to existing permitted amounts. There is a moderate to high probability of surface water gaps starting in 2020 for Basin 40 and 2030 for Basin 41 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase the size and probability of these gaps. Therefore, increasing reliance on Basins 40 and 41 surface water supplies without reservoir storage is not recommended.

Increasing Reliance on Groundwater

Currently, about 65% of the total demand is met from the Blaine aquifer, primarily for Crop Irrigation, and about 30% is met from non-delineated minor aquifers along the Red River and Sandy Creek. Under baseline demand, storage depletions of these aquifers are expected to increase due largely to the growth in Crop Irrigation demand. The projected growth in surface water and alluvial groundwater use for irrigation could be supplied by the Blaine aquifer, which would result in about 1.5 times the projected bedrock groundwater storage depletions under the baseline scenario. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. The impacts may be intensified by the geology of the aquifer; water may be obtained from cavities, solution channels, and fractures in the rock, where depletions could create changes in these features that may intensify the effect of storage depletions on a local level. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water could be considered a long-term water supply option, but may require additional infrastructure and increasing operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

The majority of current alluvial groundwater rights are in non-delineated minor aquifers; therefore, the typical yields, volume of stored water, and water quality are unknown due to lack of sufficient data. Increasing reliance on these supplies is not recommended without site-specific information.

Artificial recharge has been conducted in the Blaine aquifer since the late 1960s. In 1997, a groundwater recharge study was performed by the OWRB to determine the effectiveness of artificial recharge wells in these basins. The study found that on average, one recharge well could recharge the aquifer at a rate of about half that of the water withdrawal from an irrigation well (recharge of 70 AFY compared to average annual pumping of 142 AFY per irrigation well). Increasing use of this practice could be effective at reducing the effects of localized storage depletions in Basins 40 and 41.

Use of Marginal Quality Water

Basins 40 and 41 were found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers, such as the Blaine aquifer. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. The USGS is currently conducting a 3-year study (scheduled for completion in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states. Brackish groundwater underlies the entire basin and should be evaluated as a potential short– to long-term water supply option. However, these supplies will likely be less preferable than supplies from the shallower Blaine aquifer.

Basin 42

Basin 42 is a hot spot for surface water and alluvial groundwater supplies. Surface water issues are mainly associated with the basin's low physical availability of streamflow, rather than permit availability, and relatively poor water quality. The basin is also challenged by the overall size of storage depletions and for the rate of storage depletions relative to the amount of groundwater storage in the North Fork of the Red River aquifer. Shortages in the basin are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to the challenges noted, bedrock groundwater storage depletions are projected to occur by 2020. Six categories of supply options for mitigating surface water gaps and groundwater storage depletions in Basin 42 are summarized in the accompanying table and text.

Supply Options for Basin 42

Basin 42	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency • Significantly expanded M&I conservation measures and shift to crops with lower water demand	Short- to long-term solution that could reduce 2060 surface water and groundwater depletions by 9% to 37%
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Potential long-term solution, but limited in reservoir size; additional analysis required
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on the North Canadian River alluvial aquifer instead of increased surface water and bedrock groundwater use	Long-term solution with possible localized adverse impacts
Marginal Quality Water Use	• Use brackish groundwater sources for Crop Irrigation	Potential long-term applicability for irrigation of certain crops

Demand Management

Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 42 by 420 AFY and reduce the size of the annual 2060 surface water gaps by about 15% to a value of 230 AFY, alluvial groundwater storage depletions by about 10% to a value of 2,400 AFY, and bedrock groundwater storage depletions by about 9% to a value of 410 AFY. This conservation measure could benefit users throughout the basin and should be considered as a short– to long-term water supply option.

Scenario II (substantially expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 42 by 1,480 AFY and reduce the size of the annual 2060 surface water gaps by about 37% to a value of 170 AFY, alluvial groundwater storage depletions by about 37% to 1,680 AFY, and bedrock groundwater storage depletions by 33% to 300 AFY. This measure could benefit users throughout the basin and should be considered as a long-term water supply option. Additional conservation measures in the M&I demand sector may help reduce the adverse effects of localized storage depletions, but will not have a significant impact basin wide, because the basin's M&I demand is significantly less than that of the Crop Irrigation demand sector.

Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The construction of new out-of-basin reservoir supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified one Category 3 and one Category 4 potential reservoir sites in the Southwest Planning Region: Port Reservoir located in Basin 34 and the Mangum Lower Dam Site in Basin 39. Mangum Reservoir (Category 4) is the closest viable site, located only approximately six miles from the center of Basin 42, and could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 3,000 AF, an 18-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 42 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 36-inch diameter pipeline would be needed.

The OCWP updates information for the *1980 OCWP* statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 42. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use
Development of reservoir storage in Basin 42 may be an effective long-term solution to mitigate surface water gaps and the adverse effects of localized storage depletions. A new river diversion and 3,900 AF of reservoir storage at the basin outlet could meet the entire growth in demand from 2010 to 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. A detailed evaluation of the feasibility of any reservoir would be needed and should include consideration of existing land ownership, costs, geology, water quality, and permitting/compact obligations.

Increasing Reliance on Surface Water
Unlike many basins in the Southwest Region, use of surface water to meet local demand in Basin 42 through 2060 is not expected to be limited by the availability of permits. However, there is a moderate to high probability of surface water gaps starting in 2040 for the baseline demand projections. Increasing reliance on surface water use without reservoir storage would increase the size and probability of these gaps. Therefore, increasing reliance on Basin 42 surface supplies water without reservoir storage is not recommended.

Increasing Reliance on Groundwater
The North Fork of the Red River alluvial aquifer is the primary source of water in Basin 42, supplying 71% of the total demand. Under baseline demand, storage depletions are expected to occur in the North Fork of the Red River and in non-delineated minor aquifers in terrace deposits of the Salt Fork of the Red River, due largely to the growth in Crop Irrigation demand. Due to the alluvial aquifer's connection to river flows and precipitation, aquifer levels may also fluctuate naturally in response to prolonged periods of drought or above-average precipitation. The projected growth in surface water and bedrock groundwater use could instead be supplied by the North Fork of the Red River aquifer, which would result in moderate increases of about 510 AFY in projected alluvial groundwater storage depletions. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional alluvial groundwater supplies to meet the growth in surface water and bedrock could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

Bedrock groundwater supplies are from non-delineated minor aquifers; therefore, increasing reliance on these supplies is not recommended without site-specific information.

Use of Marginal Quality Water
Basin 42 was found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. The USGS is currently conducting a 3-year study (to be completed in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states. Brackish groundwater underlies the entire basin and should be evaluated as a potential short– to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Fork of the Red River aquifer. Implementation of the chloride control project on the Elm Fork of the Red River in Basins 42 and 43 could be a viable option for increasing surface water supplies.

Basin 51
Basin 51 is a surface water and alluvial groundwater hot spot. Surface water issues are mainly associated with the basin's low physical availability of streamflow, lack of available streamflow for new permits, and to a lesser extent its poor water quality. Storage depletions are expected to present water supply challenges based on the overall size of the depletions and for the rate of those depletions relative to the amount of groundwater storage in the North Canadian River and Canadian River alluvial aquifers. More detailed information on this basin is available in the OCWP *Central Watershed Planning Region Report*. In addition to surface water gaps and alluvial groundwater storage depletions, bedrock groundwater storage depletions may occur by 2020. Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 51 are summarized in the accompanying table and text.

Supply Options for Basin 51

Basin 51	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency • Substantially expanded M&I conservation measures and shift to crops with lower water demand	Short- to long-term solution that may significantly reduce or eliminate surface water gaps and groundwater storage depletions
Out-of-Basin Supplies	• Potential reservoir sites in other basins may provide supplies. Terminal storage in-basin could reduce the size of the pipe needed to convey supplies in basin	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Potential long-term solution; surface water is fully allocated and additional analyses would be required
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on North Canadian River and Canadian River alluvial aquifers	Long-term solution; may have localized adverse impacts
Marginal Quality Water Use	• Use brackish groundwater sources for Crop Irrigation	Use brackish groundwater sources for Livestock or, with treatment, for M&I demand

Demand Management

Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 51 by 3,560 AFY and reduce the size of the annual 2060 surface water gaps by about 79% to a value of 340 AFY, alluvial groundwater storage depletions by about 73% to a value of 770 AFY, and bedrock groundwater storage depletions by about 80% to a value of 20 AFY. Moderately expanded conservation measures could benefit users throughout the basin and should be considered as a short– to long-term water supply option.

Scenario II (substantially expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 51 by 5,440 AFY and may reduce the size of the annual 2060 surface water gaps by 97% to a value of 50 AFY, alluvial groundwater storage depletions by 96% to a value of 110 AFY, and could eliminate bedrock groundwater storage depletions. These measures could benefit users throughout the basin and should be considered as a long-term water supply option.

Out-of-Basin Supplies

Oklahoma City's Lake Overholser in Basin 51 and Hefner Lake in Basin 64 receive substantial supplies out-of-basin from Canton Reservoir in Basin 52 through releases to the North Canadian River. It is anticipated that Basin 51 will continue to receive supplies from these resources as allocated by existing permits. Oklahoma City currently provides supply to several users in the basin, including El Reno, Yukon and the Canadian County Water Authority. Increasing regionalization of supplies could reduce future gaps and depletions.

Development of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of new out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level. To supply the entire Basin 51 increase in M&I demand from 2010 to 2060, an additional 3,280 AFY of out-of-basin supplies would be required. With new terminal storage of 900 AF, a 20-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 51 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 30-inch diameter pipeline would also be recommended.

The OCWP *Reservoir Viability Study* identified five Category 4 sites that are within a 50-mile radius of Basin 51. Hennessey (estimated yield of 18,819 AFY) and Navina (34,615 AFY estimated yield) in Basin 64 of the Central Planning Region; Hydro (114,934 AFY yield) in Basin 59 in the West Central Region; and Sheridan (23,525 AFY yield) and Skeleton (41,448 AFY yield) in Basin 63 of the Upper Arkansas Region. The Hydro Reservoir site is approximately 20 miles from the center of Basin 51; the Hennessey, Navina, Sheridan, and Skeleton Reservoir sites are approximately 35-45 miles from the center of Basin 51. These sites might also be considered for potential regional water supply projects.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system that encompasses Basin 51. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that construction of the entire system would not be feasible under current technology and economic constraints. However, certain segments, such as additional conveyance of water from southeast to central Oklahoma, are currently under consideration.

Reservoir Use

Additional reservoir storage in Basin 51 could supplement supplies during dry months. However, surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. If permittable, the entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 19,500 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state; no viable sites were identified in Basin 51.

Increasing Reliance on Surface Water Supplies

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a high probability of surface water gaps in Basin 51 starting in 2020 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase these gaps. Therefore, increasing reliance on Basin 51 surface water supplies is not recommended.

Increasing Reliance on Groundwater Supplies

The North Canadian River and Canadian River alluvial aquifers are the primary sources of water supply in Basin 51, comprising 59% of the total demand. Under baseline demand, storage depletions are expected to occur in these aquifers due largely to the growth in the M&I and Thermoelectric Power demand sectors. The projected growth in surface water use could be supplied by groundwater from the North Canadian River or Canadian River alluvial aquifers, which would result in moderate (520 AFY) increases in projected alluvial groundwater storage depletions. Due to the alluvial aquifers' connection to river flows and precipitation, aquifer levels may also fluctuate naturally due to prolonged periods of drought or above-average precipitation. While increasing use of alluvial water would increase the amount of alluvial groundwater storage depletions, the depletions would be minimal compared to the total amount of water in storage. Therefore, the development of additional alluvial groundwater supplies to meet the growth in surface water demand could be considered a long-term water supply option, but may require additional infrastructure and increasing operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

Bedrock groundwater supplies are from the El Reno minor aquifer; therefore, increasing reliance on these supplies is not recommended without site-specific information.

The Aquifer Recharge Workgroup identified a site near El Reno (site # 27) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the North Canadian River to recharge the North Canadian alluvial terrace aquifer. However, there was not sufficient water available for new permits, so a detailed analysis was not completed at this site.

Use of Marginal Quality Water

Basin 51 was found to have significant brackish marginal quality groundwater sources that could be used to meet a portion of the Basin's M&I and Livestock demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers. The use of these supplies for M&I demand may require advanced treatment processes, such as reverse osmosis (RO) or ion exchange. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. The USGS is currently conducting a 3-year study (to be completed in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states. Brackish groundwater underlies the entire basin and should be evaluated as a potential short– to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Canadian River aquifer.

Basin 54

Basin 54 is a bedrock groundwater hot spot, where storage depletions are expected to present water supply challenges based on the overall size of the depletions and for the rate of those depletions relative to the amount of groundwater storage in the Ogallala aquifer. Shortages in the basin are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on this basin is available in the OCWP *Panhandle Watershed Planning Region Report*. In addition to bedrock groundwater storage depletions, alluvial groundwater storage depletions may occur in Basin 54 by 2020 and surface water gaps may occur by 2030. Surface water is also fully allocated. Six categories of supply options for mitigating groundwater storage depletions in Basin 54 are summarized in the accompanying table and text.

Demand Management

Scenario I (moderately expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 54 by 1,440 AFY and reduce the size of the annual 2060 surface water gaps by about 6% to a value of 150 AFY, alluvial groundwater storage depletions by about 13% to a value of 340 AFY, and bedrock groundwater storage depletions by about 15% or to a value of 7,720 AFY. This conservation measure could benefit users throughout the basin and should be considered as a short– to long-term water supply option.

Supply Options for Basin 54

Basin 54	Option	Feasibility
Demand Management	• Moderately expanded M&I conservation measures and increased sprinkler irrigation efficiency • Significantly expanded M&I conservation measures and shift to crops with lower water demand	Short- to long-term solution that could reduce 2060 bedrock groundwater depletions up to 99%
Out-of-Basin Supplies	• Englewood Reservoir or Statewide Water Conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Potential long-term solution; additional analyses needed
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on the Ogallala aquifer	Long-term solution; may have localized adverse impacts
Marginal Quality Water Use	• Use of marginal water quality sources	No significant sources identified; site-specific potential for reuse of oil and gas flowback and produced water for oil and gas drilling and operations

Scenario II (substantially expanded) irrigation and M&I conservation measures could reduce the total associated 2060 demand in Basin 54 by 10,270 AFY and reduce the size of the annual 2060 surface water gaps by about 38% to a value of 100 AFY, alluvial groundwater storage depletions by about 85% to 60 AFY, and bedrock groundwater storage depletions by as much as 99% to 70 AFY. This measure could benefit users throughout the basin and should be considered as a long-term water supply option. Additional conservation measures in the M&I demand sector may help reduce the adverse effects of localized storage depletions, but will not have a significant impact basin wide because the basin's M&I demand is significantly less than that of the Crop Irrigation demand sector.

Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potential reservoir sites in the Panhandle Region: Forgan (Category 3) and Englewood (Category 4) Reservoirs, both located on the Cimarron River in Basin 65. Englewood Reservoir would be 45 miles or more away from the majority of users in Basin 54, but could provide an estimated dependable yield of 36,967 AFY from 424,400 AF of total storage. This reservoir also would require approval of the Kansas-Oklahoma Arkansas River Compact Commission. With new terminal storage of about 5,000 AF, a 30-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 54 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 48-inch diameter pipeline would be needed. The reservoir would yield more water then needed to meet Basin 54's demands, thus the site could be considered as a potential regional project.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system that encompasses Basin 54. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

Fort Supply Lake is located at the basin outlet and was built for flood control and conservation storage. The reservoir has a normal pool storage capacity of 13,900 AF, which includes 400 AF of water supply storage yielding 224 AF/year. Fort Supply Lake is operated by the U.S. Corps of Engineers and may provide additional supplies in the future.

Additional reservoir storage could mitigate surface water gaps. The flow in Basin 54 has been fully permitted and is expected to severely limit the size and location of new reservoirs. However, if permittable, a river diversion and 200 AF of reservoir storage at the basin outlet could supply the entire increase in surface water use through 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps. A detailed analysis is needed to determine the feasibility of using reservoir storage to meet future groundwater demands.

The OCWP *Reservoir Viability Study* evaluated the potential for new reservoirs throughout the state; no viable new sites were identified for construction in Basin 54.

Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a moderate to high probability of surface water gaps starting in 2040 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase the size and probability of these gaps. Therefore, increasing reliance on surface water supplies without reservoir storage is not recommended.

Increasing Reliance on Groundwater

The Ogallala bedrock aquifer is the primary source of water in Basin 54, supplying up to 95% of the total water demand. Water levels in Basin 54's portion of the Ogallala aquifer have remained relatively constant or have been increasing in recent years (OWRB Mass Well Measurement 2011). Under baseline demand, storage depletions are expected to increase due largely to the growth in Crop Irrigation demand. The projected growth in surface water and alluvial groundwater use could instead be supplied by the Ogallala aquifer, which would result in small (550 AFY) increases in projected storage depletions. Additionally, some M&I water users could consider obtaining wholesale water supplies from water providers with wells in more dependable portions of the Ogallala aquifer. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water and bedrock groundwater could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

Use of alluvial groundwater instead of increasing surface water use would increase alluvial groundwater storage depletions by 100 AFY by 2060. However, the majority of alluvial groundwater use is from non-delineated minor aquifers on Wolf Creek. Therefore, increasing reliance on these supplies is not recommended without site-specific information.

The OCWP Aquifer Recharge Workgroup identified a site near the City of Woodward (site #2) as potentially feasible for aquifer recharge and recovery. Water could be withdrawn from the Upper North Canadian River to recharge the Ogallala aquifer. Further study of aquifer recharge feasibility and pilot testing may be warranted for this location.

Use of Marginal Quality Water

Basin 54 was not found to have significant marginal quality sources or significant potential to offset demand. The Oil and Gas demand sector could potentially use marginal quality water from oil and gas flowback or produced water for drilling and operational activities. Opportunities to reuse flowback or produced water should be considered on an individual well field basis for cost-effectiveness relative to other available supplies.

Basins 55 & 66

Basins 55 and 66 (Cimarron Headwaters) are adjacent basins with very similar water supply needs and resources, therefore, they were evaluated as a single hot spot. Basins 55 and 66 are bedrock groundwater hot spots and Basin 66 is also a surface water hot spot. Storage depletions in both basins are expected to present water supply challenges based on the overall size of the depletions and for the rate of those depletions relative to the amount of groundwater storage in the Ogallala aquifer. Surface water issues in Basin 66 are mainly due to the basin's low physical availability of streamflow and lack of available streamflow for new permits. Shortages in the basins are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on these basins is available in the OCWP *Panhandle Watershed Planning Region Report*. In addition to challenges noted above, Basin 55 is also fully allocated and surface water gaps and alluvial groundwater storage depletions may occur by 2020. Alluvial groundwater storage depletions may occur in Basin 66 by 2050. Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basins 55 and 66 are summarized in the accompanying table and text.

Supply Options for Basins 55 & 66

Basins 55 & 66	Option	Feasibility
Demand Management	• Increased irrigation efficiency • Shift to crops with lower water demand	Short- to long-term solution that may reduce groundwater storage depletions by 30% to about 90% and surface water gaps by up to 75%
Out-of-Basin Supplies	• Englewood Reservoir or Statewide Water Conveyance	Potential long-term solution
Reservoir Use	• Development of new reservoirs	Not feasible
Increasing Reliance on Surface Water	• Increased reliance on surface water supplies, without reservoir storage	Not feasible
Increasing Reliance on Groundwater	• Increased reliance on the Ogallala aquifer instead of increased surface water and alluvial groundwater use	Long-term solution; with probable localized adverse impacts
Marginal Quality Water Use	• Use of marginal water quality sources	No significant sources identified

Demand Management

Scenario I (moderately expanded) irrigation measures in Basins 55 and 66 and M&I conservation measures in Basin 55 (Basin 66 does not have any M&I demand) could reduce the total associated 2060 demand in both basins by 16,900 AFY and reduce the size of the combined annual 2060 surface water gaps by about 29% to a value of 510 AFY, alluvial groundwater storage depletions by about 28% to a value of 280 AFY, and bedrock groundwater depletions by up to 32% or a value of 35,750 AFY.

From an individual basin perspective, implementing conservation in both sectors is only expected to reduce the 2060 surface water gap by 140 AFY in Basin 55 and 70 AFY in Basin 66. Implementing conservation in both sectors could reduce the 2060 alluvial groundwater storage depletions by 110 AFY in Basin 55; however, no reduction is expected in Basin 66. Implementing conservation in both sectors could reduce the 2060 bedrock groundwater storage depletions by 15,510 AFY in Basin 55 and 1,090 AFY in Basin 66.

Moderately expanded conservation measures could benefit users throughout the basins and should be considered as a short– to long-term water supply option. However, while additional conservation measures in the M&I demand sector in Basin 55 (Basin 66 does not have any M&I demand) may help reduce the adverse effects of localized storage depletions, this measure will not have a significant impact basin wide because the basin's M&I demand is significantly less than that of the Crop Irrigation demand sector.

Scenario II (substantially expanded) irrigation measures in Basins 55 and 66 and M&I conservation measures in Basin 55 could reduce the total associated 2060 demand in both basins by 67,620 AFY and reduce the size of the combined annual 2060 surface water gaps by about 86% to a value of 100 AFY, alluvial groundwater depletions by 85% to a value of 60 AFY, and bedrock groundwater depletions by up to 87% to a value of 6,650 AFY. Based on an individual basin perspective, the combined Scenario II demand reduction in both sectors may decrease 2060 surface water gaps by 260 AFY in Basin 55 and 360 AFY in Basin 66. Alluvial groundwater storage depletions may be decreased by 310 AFY in Basin 55 and may be eliminated in Basin 66. Bedrock groundwater storage depletions in 2060 may be reduced by 41,040 AFY in Basin 55 and by 4,660 AFY in Basin 66. These decreases in gaps and storage depletions are between 80% and 100% of the demand from the supply sources. While these reductions are expected to decrease the probability of gaps, the probability will remain high due to the high frequency of low to no flow months. This measure could benefit users throughout the basins and should be considered as a long-term water supply option.

Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies needs to be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potentially viable reservoir sites in the Panhandle Region: Forgan (Category 3) and Englewood (Category 4) Reservoirs, both located on the Cimarron River in Basin 65. Englewood Reservoir would be 90 miles or more away from the majority of users in Basins 55 and 66, but could provide an estimated dependable yield of 36,967 AFY from 424,400 AF of total storage. Basins 55 and 66 could use the entire potential yield of the Englewood site without meeting their full growth in demand from 2010 to 2060. This reservoir also would require approval of the Kansas-Oklahoma Arkansas River Compact Commission. With new terminal storage of about 13,000 AF, a 48-inch diameter pipe would be needed to bring out-of-basin supplies equal to the potential yield into Basins 55 and 66 for further distribution to users and reduce gaps and storage depletions. With no terminal storage, a 72-inch diameter pipeline would be needed.

The OCWP *Water Conveyance Study* updates information for the *1980 OCWP* statewide water conveyance system that encompasses Basins 55 and 66. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

Reservoir Use

The development of reservoir storage in Basins 55 and 66 is not recommended. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state; no viable sites were identified in Basins 55 and 66. Furthermore, surface water has been fully permitted, which is expected to severely limit the size and location of new reservoirs.

Increasing Reliance on Surface Water

Surface water in the basins is fully allocated, limiting diversions to existing permitted amounts. There is a moderate to high probability of surface water gaps in both basins starting in 2020 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase these gaps. Therefore, increasing reliance on surface water supplies without reservoir storage is not recommended.

Increasing Reliance on Groundwater

The primary source of water in these basins is bedrock groundwater from the Ogallala aquifer, which provides 98% of the total demand. Water levels in the Ogallala aquifer have declined substantially in many areas (OWRB 2006); however, the rate of water level declines has slowed due to the efforts of the Panhandle community (OWRB Mass Well Measurement 2011). Under baseline demand, storage depletions are expected to increase due largely to the growth in Crop Irrigation in the basins. These declining water levels could result in higher pumping costs, the need for deeper wells, and potentially changes to well yields or water quality. The projected growth in surface water and alluvial groundwater use could instead be supplied by the Ogallala aquifer, which would result in minimal (800 AFY by 2060) increases in projected 2060 storage depletions. Additionally, some M&I water users could consider obtaining wholesale water supplies from water providers with wells in more dependable portions of the Ogallala aquifer. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water and alluvial groundwater demand could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. In the long term, Demand Management and other supply options may provide more consistent supplies and may be more cost-effective.

Use of additional alluvial groundwater instead of increasing surface water use would increase alluvial groundwater storage depletions by 190 AFY by 2060. However, the majority of alluvial groundwater use is from non-delineated minor aquifers. Therefore, increasing reliance on these supplies is not recommended without site-specific information

Use of Marginal Quality Water

Basins 55 and 66 were not found to have significant marginal quality water sources or significant potential to offset demand with MQW. The Oil and Gas demand sector could potentially use marginal quality water for drilling and operational activities, but the use of this source could not be estimated, since any use would be on a well-specific basis.

Tools Developed During the OCWP Process

Data analysis has multiple facets and approaches. Analysis and synthesis of all the data involved in creating a statewide water plan with the goal of providing useful information, suggesting conclusions, and supporting decision-making involves the use of numerous methods and approaches. Several tools were developed during the process of the *2012 OCWP Update* that will be helpful as the Water Plan is implemented. These tools provide the opportunity for future dynamic statewide water planning, as well as planning at the local and regional level. These tools can help save steps when developing complex statistical analyses and can help provide meaningful information on a systematic level for decision-making purposes. OCWP planning tools, as well as other tools that might be useful for planning purposes, are summarized below.

OCWP Planning Tools

Oklahoma H2O: is a Microsoft Access and geographical information system (GIS) based analysis tool that was created to compare projected demand with physical supplies for each of the 82 OCWP basins. This tool is used in the planning process to: (1) identify areas of potential wet water shortages (physical supply availability constraints); (2) more closely examine demand and supplies, and (3) evaluate potential water supply solutions. The supply availability tool was developed to allow flexibility to perform a variety of "what if" scenarios, and it allows for informed decision-making based on a variety of factors. The analysis incorporates data on supply and demand to determine the available wet water (surface water and groundwater) in each OCWP basin.

Approach for Statewide Reservoir Yield Analysis: substantiates a method that can be used across the state for determining reservoir yields. The approach blends common elements of standard practices employed by the United States Bureau of Reclamation (Reclamation), the United States Army Corps of Engineers (USACE), and Camp Dresser and McKee Inc. (CDM). The proposed approach provides for analysis of multi-reservoir systems without necessitating complex computer programs with specialized programming codes. The proposed tool is user-friendly and flexible, thus well-suited to these types of analyses.

Public Water Supply Planning Guide: specifically designed to show public water providers how to use the information contained in the OCWP Watershed Planning Region reports to: (1) assess their current and future water supplies and demands and (2) develop a water supply plan to meet their long-term water needs.

Infrastructure Decision Tools

Oklahoma Advantages Assessment and Scoring for Infrastructure Solutions (OASIS): is a web-based application that quantifies the social, economic, and environmental benefits of infrastructure investments to communities and the state, beyond regulatory compliance. Utilizing this computer program, developed specifically for Oklahoma, communities can enter details regarding their current or pending infrastructure investments. Resulting output will allow community leaders to document and/or better articulate the benefits of the investment, including:

- Impacts on economic growth
- Impacts on quality of life
- System sustainability
- Cost of delaying improvements
- Reduced health risks from waterborne illnesses
- Energy cost savings from efficiency upgrades
- Impacts to property values

Loan and Grant Resource Guide: is a free publication available from the OWRB that identifies potential grant and loan funding sources for water and wastewater projects. The guide assists communities locating potential funding sources, the type of funding they provide and relevant contact information.

Capacity Development Program (Drinking Water): is administered by the Oklahoma Department of Environmental Quality and evaluates the technical, managerial, and financial capacity of a utility. The program provides a variety of training and tools to assist utilities in improving and maintaining capacity.

Rate Comparison Tool: was developed to assist communities in comparing the cost of traditional financing to OWRB loan programs. The program is available free to the public from the OWRB.

Drinking Water and Wastewater Infrastructure Needs

In order to assess the magnitude of drinking water infrastructure needs, the OCWP prepared cost estimates to characterize Oklahoma's needs for the next 50 years. Even though wastewater infrastructure needs were not analyzed for inclusion in the OCWP Watershed Planning Region reports, they have a significant relation to drinking water needs, especially as water managers consider overall infrastructure funding requirements. Therefore, cost estimates were also prepared to characterize Oklahoma's wastewater infrastructure needs in the next fifty years.

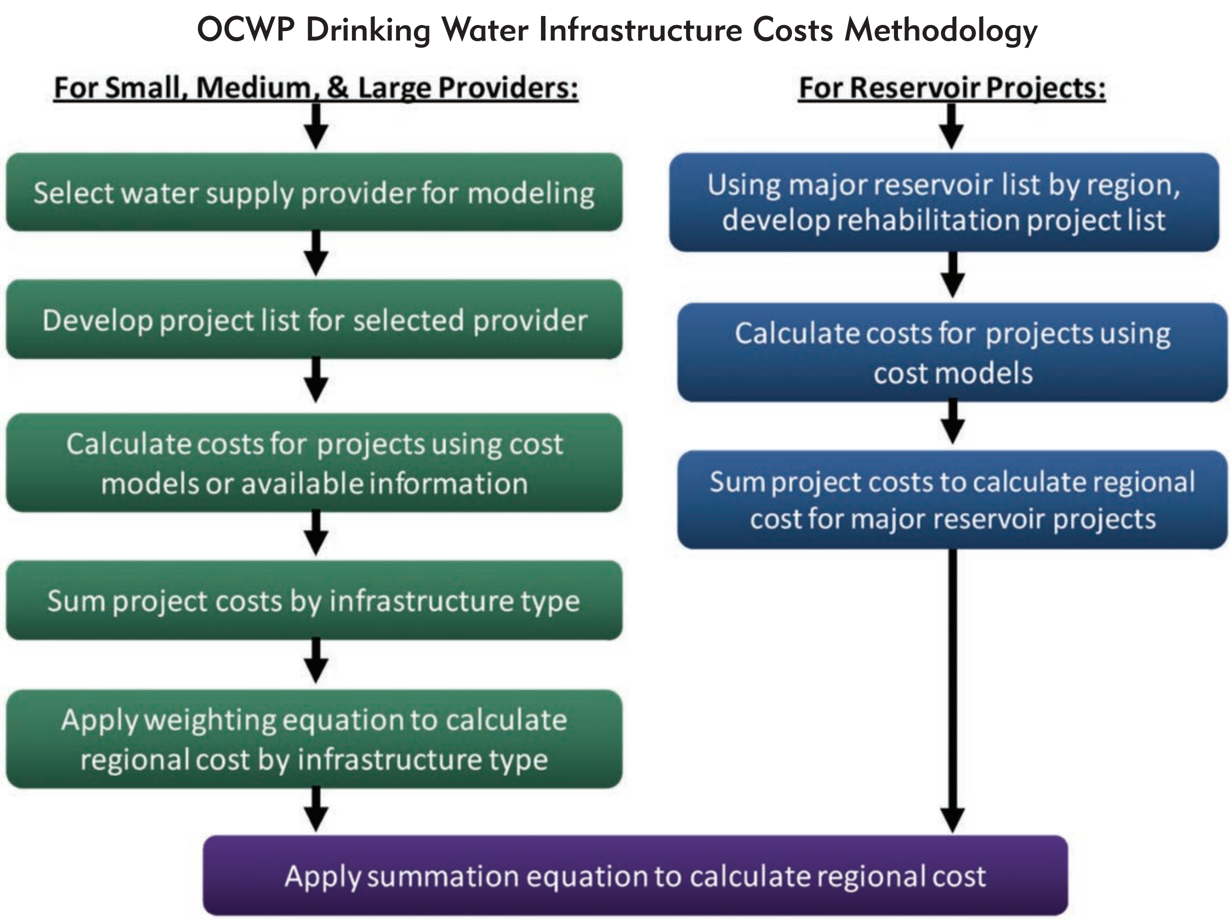
Projected cost estimates were developed for a selection of existing water and wastewater providers. These costs were weighted, using a methodology similar to the U.S. Environmental Protection Agency (EPA) methods for determining national water and wastewater infrastructure costs. Cost estimates were derived for each of the 13 Watershed Planning Regions and drinking water infrastructure funding needs were included in the Watershed Planning Region reports, consistent with the analysis of other water supply needs. The regional cost estimates were then summed to provide a statewide cost estimate to meet drinking water needs for the next 50 years. This section briefly summarizes the cost estimates at both the state and regional levels. The drinking water and wastewater infrastructure needs assessment reports (CDM, 2011) provide a much greater level of detail for each region.

OCWP Drinking Water Infrastructure Needs Methodology

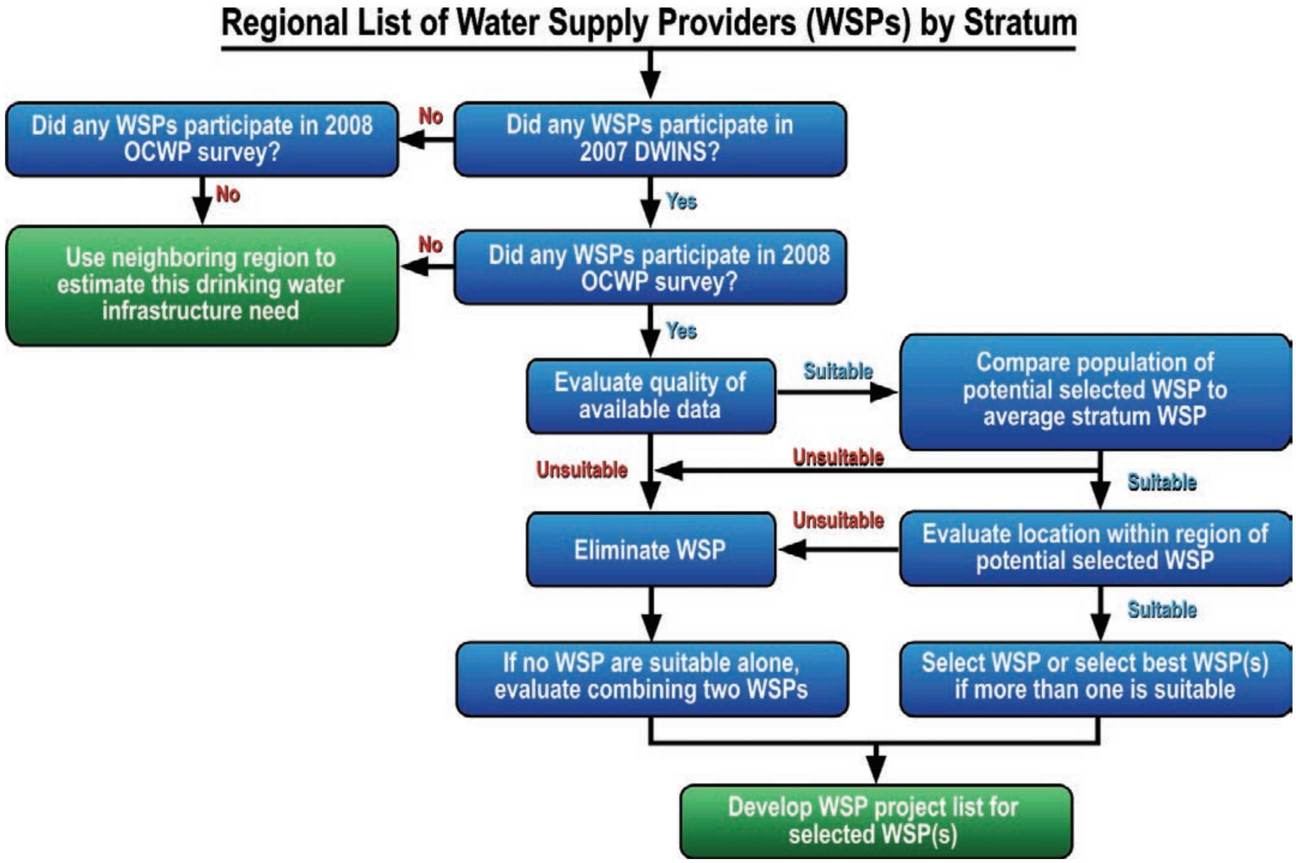
The basis for the OCWP cost estimating approach was EPA's methodology presented in the report *2009 Drinking Water Infrastructure Needs Survey (DWINS) and Assessment: Fourth Report to Congress*. For this report, the term "2007 DWINS" is used to encompass the EPA method, cost models, and results associated with the most recent survey.

To develop the water infrastructure costs, EPA sent a survey requesting drinking water infrastructure needs information to all large providers and a statistically significant portion of medium providers in each state. For small providers, EPA sent qualified personnel to complete surveys for a statistically significant portion of small systems across the country. Projects were limited to water system needs eligible for the Drinking Water State Revolving Fund (DWSRF) program. The survey collected project descriptions and cost estimates if available. When cost estimates were unavailable, EPA utilized cost models to estimate the project costs.

EPA summed all eligible project costs to develop the state need for large water systems. The project costs included in the survey were weighted to determine the state need for medium water systems. To determine the state's small system need, EPA calculated a national average small system need and multiplied it by the number of small providers in Oklahoma. Calculated project costs were multiplied by adjustment factors to account for regional differences in construction



Water Supply Provider Project List Development



costs. Using the collected information, EPA created state-level water needs that were summed, along with separately developed American Indian and Alaskan Native village water systems costs, to develop a national 20-year need. Results were presented by system size and project type, which included distribution and transmission, treatment, storage, source, and other factors.

The OCWP method is similar to EPA's 2007 DWINS approach. Cost estimates were developed according to the 13 OCWP Watershed Planning Regions. A few of the key similarities between the OCWP and 2007 DWINS methodologies include the following:

- The OCWP study used the same criteria for system size, with large systems serving more than 100,000 people, medium serving between 3,301 and 100,000 people, and small serving 3,300 and fewer people. Categorization of water providers was based on projected 2060 population and project size was based on projected 2060 total demands including retail, system losses, and sales.
- The OCWP study used the same classification for infrastructure type: distribution and transmission, treatment, storage, source, and other. (Generally, the definitions of each category are the same between the 2007 DWINS and OWRB method.)
- The OCWP study used the same source water classification.
- The OCWP study used the same definition of project costs.
- The OCWP study used the same 2007 DWINS cost models except when unavailable.
- The OCWP study excluded all new reservoir projects similar to the 2007 DWINS. While new reservoirs are a key part of meeting current and future water supply needs for Oklahoma, the cost associated with developing new reservoirs depends significantly on local decisions. These decisions include whether to consider other opportunities besides drinking water supplies that can be associated with reservoir construction, such as additional storage (or larger reservoirs) for flood control, recreation, aesthetics, or other purposes. Local preferences will also make a difference in attitudes regarding project cost versus reliability and site location.

A few of the key differences between the OCWP and 2007 DWINS methodologies include:

- The OCWP study included all types of projects, not just those eligible for the DWSRF program. Examples of projects that were included in the OCWP study, but not in the 2007 DWINS, are dam and reservoir rehabilitation projects and projects specifically for new growth. Costs were split into DWSRF eligible and non-eligible categories to help define the level of financial support that could potentially be sought by applicants for DWSRF loans administered by OWRB.

- The OCWP study used a 50-year planning horizon compared to the 20-year planning period used by the 2007 DWINS and used 2020, 2040 and 2060 incremental periods to calculate costs.
- The OCWP study used several sources of information, including Oklahoma system-specific information available from the 2007 DWINS; information from the 2008 OCWP Water Provider Survey; and regional or provider water studies and master plans to supplement available information.
- The OCWP study included projects that have been funded since the 2007 and 2008 surveys.
- The OCWP study developed project lists for selected providers while the 2007 DWINS relied on projects submitted by each survey respondent.

Many factors were evaluated in order to select water supply providers for inclusion in the OCWP study cost modeling. The first step was to group the OCWP water providers by stratum: large, medium, small, surface water, and groundwater. OCWP providers are those included in the 2008 OCWP survey and for which water demand projections were created and included in the Watershed Planning Region reports. All large providers were selected for cost modeling. For other stratums, selecting at least one water supply provider in each stratum was the goal, with the quality and quantity of available data being the most important selection criteria. Where this was not possible, other methods were used to estimate costs.

The next cost-modeling step was to develop a project list for each selected provider. To reduce the subjectivity of this step, a list of standard assumptions was developed and used unless better information was available. The 2007 DWINS information provided project name and basic design information required for cost modeling. When the 2007 DWINS projects contained cost information, it was included in the OCWP analysis.

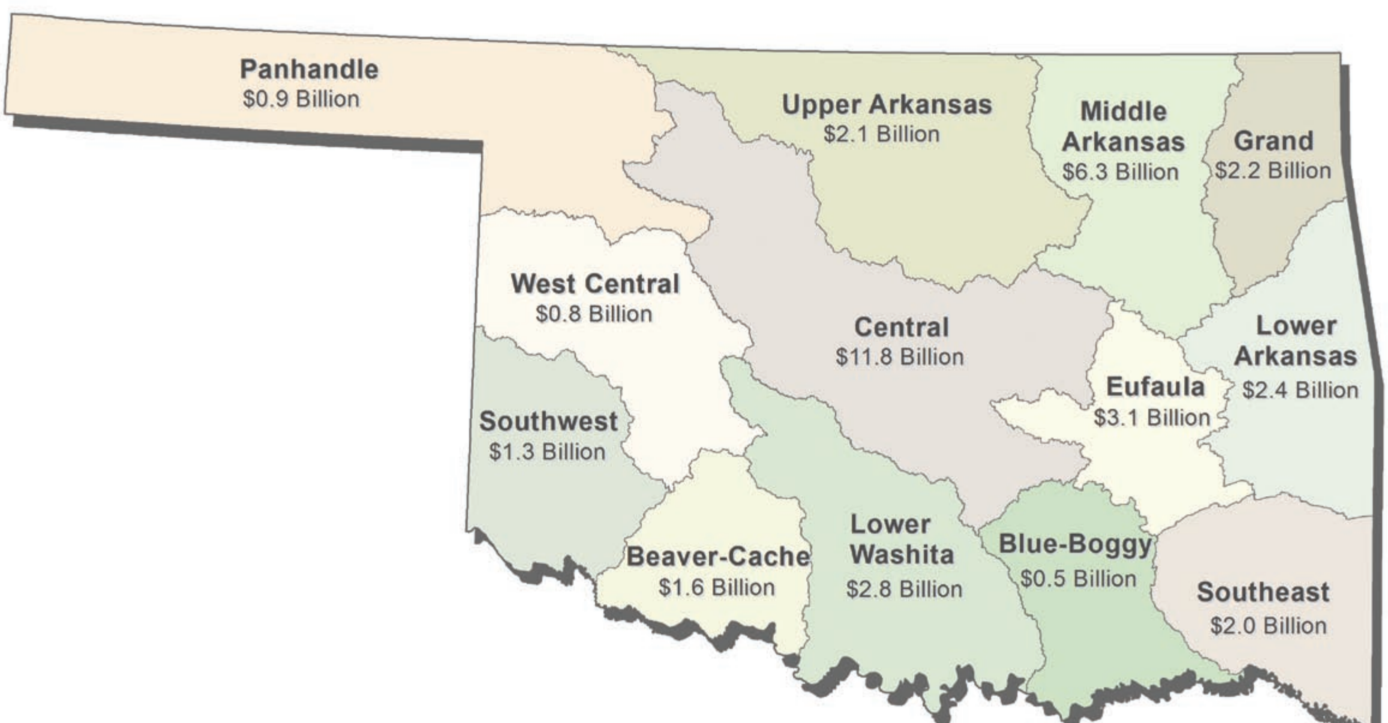
Project development worksheets for surface water and groundwater sources were developed. Information provided in the 2008 OCWP provider survey and additional information obtained through other OCWP activities were used to complete the form. The OCWP standard assumptions also supplemented the available information as needed. The worksheet provided a standard method for estimating types of projects needed, project size, and the project date. The intent was not to make detailed project lists, but to provide basic project information that enabled use of the 2007 DWINS cost models. Completed project lists and costs were used to calculate regional and statewide drinking water infrastructure costs.

Regional and Statewide Drinking Water Cost Estimates

Fifty-five of the 785 OCWP providers were selected for cost modeling. The selected providers' costs were extrapolated using the methodology outlined to calculate the infrastructure costs of the region and state.

Across the state, approximately $38 billion (in 2007 dollars) is required to meet the drinking water infrastructure needs for the next 50 years. Costs are separated into those that are and are not eligible for DWSRF loans to facilitate an analysis of potential funding and financing programs. Small providers have the largest overall drinking water infrastructure costs comprising approximately 46% of the state's need. The largest infrastructure costs occur in the 2041-2060 period.

Projected Statewide Drinking Water Infrastructure Cost by Region (2007 Dollars)



Drinking Water Infrastructure Cost Summary by Region

Region	Present-2020 Infrastructure Need	2021-2040 Infrastructure Need	2041-2060 Infrastructure Need	Total Period Infrastructure Need
	Millions of 2007 dollars			
Beaver-Cache	$740	$490	$380	$1,610
Blue-Boggy	$100	$360	$40	$500
Central	$2,700	$990	$8,130	$11,820
Eufaula	$530	$1,570	$1,030	$3,130
Grand	$510	$1,040	$600	$2,150
Lower Arkansas	$440	$580	$1,370	$2,390
Lower Washita	$1,200	$1,140	$470	$2,810
Middle Arkansas	$1,300	$1,420	$3,540	$6,260
Panhandle	$340	$360	$240	$940
Southeast	$280	$1,100	$640	$2,020
Southwest	$400	$560	$310	$1,270
Upper Arkansas	$1,040	$580	$490	$2,110
West Central	$100	$430	$250	$780
Total	**$9,680**	**$10,620**	**$17,490**	**$37,790**

Source: Drinking Water Needs Assessment by Region, CDM, April 2011

Statewide Drinking Water Infrastructure Cost Summary by Category

Category[1]	Potential Funding Source[2]	Present-2020 Infrastructure Need	2021-2040 Infrastructure Need	2041-2060 Infrastructure Need	Total Period Infrastructure Need
	Millions of 2007 dollars				
Small	DWSRF Eligible	$3,400	$4,990	$8,730	$17,120
	Non-DWSRF Eligible	$40	$70	$70	$180
Small Subtotal		$3,440	$5,060	$8,800	$17,300
Medium	DWSRF Eligible	$4,320	$4,050	$6,120	$14,490
	Non-DWSRF Eligible	$50	$60	$60	$170
Medium Subtotal		$4,370	$4,110	$6,180	$14,660
Large	DWSRF Eligible	$1,720	$1,170	$1,690	$4,580
	Non-DWSRF Eligible	$50	$20	$20	$90
Large Subtotal		$1,770	$1,190	$1,710	$4,670
Reservoir[3]	DWSRF Eligible	$0	$0	$0	$0
	Non-DWSRF Eligible	$100	$250	$810	$1,160
Reservoir Subtotal		$100	$250	$810	$1,160
Total		**$9,680**	**$10,610**	**$17,500**	**$37,790**

Source: Drinking Water Needs Assessment by Region, CDM, April 2011

1 Large systems are those serving more than 100,000 people, medium systems are those serving between 3,301 and 100,000 people and small systems are those serving 3,300 and fewer people. The "reservoir" category includes all regional reservoir rehabilitation projects.

2 This study assumes that reservoir rehabilitation and distribution projects for new growth are non-DWSRF eligible. All other projects were assumed to be DWSRF eligible. Costs were split into these categories to help define the potential level of financial support that could be sought by DWSRF loan applicants.

3 Projects that address source water protection may be eligible for funding under the CWSRF Program. Eligible activities include tree plantings and other protection activities that take place in wellhead protection or surface water drainage areas. Land for reservoirs, including impoundment or dam, is eligible.

a. Small differences in values may result from rounding.

Inflation Adjusted Drinking Water Infrastructure Need

	Present-2020 Infrastructure Need (millions of 2007 dollars)	2021-2040 Infrastructure Need (millions of 2007 dollars)	2041-2060 Infrastructure Need (millions of 2007 dollars)	Total Period Infrastructure Need (millions of 2007 dollars)
Cost in 2007 Dollars	$9,680	$10,690	$17,530	$37,900
Cost Inflation Adjusted	$11,090	$19,220	$56,720	$87,030

Source: Financial Assessment of the Oklahoma Comprehensive Water Plan, FirstSouthwest, April 2011

Inflation Adjusted DWSRF-Eligible Drinking Water Infrastructure Need

	Present-2020 Infrastructure Need (millions of 2007 dollars)	2021-2040 Infrastructure Need (millions of 2007 dollars)	2041-2060 Infrastructure Need (millions of 2007 dollars)	Total Period Infrastructure Need (millions of 2007 dollars)
DWSRF Eligible	$10,810	$18,500	$53,640	$82,950
Non-DWSRF Eligible	$ 280	$720	$3,080	$4,080
Total Costs	**$11,090**	**$19,220**	**$56,720**	**$87,030**

Source: Financial Assessment of the Oklahoma Comprehensive Water Plan, FirstSouthwest, April 2011

To quantify the true costs of these projects over time, an analysis was conducted to factor inflation into the cost estimates. A rate of inflation of 2.98% was calculated based on the average U.S. Consumer Price Index for the past 15 years plus 50 basis points. The $38 billion infrastructure cost increases to roughly $87 billion when an inflation factor of 2.98% is applied. This difference is a result of the 50-year term for the planning horizon and the compounding effect of the inflation rate during that period.

OCWP Wastewater Infrastructure Needs Methodology

The basis for the OCWP cost estimating approach was EPA's methodology presented in the report *2008 Clean Watersheds Needs Survey (CWNS) and Assessment: Fourth Report to Congress*. Hereafter, the term "2008 CWNS" is used to encompass the EPA method, cost models, and results associated with the most recent survey as described below.

To develop the wastewater infrastructure costs, EPA established a data entry portal (DEP). This DEP allows wastewater utilities to update and enter new documented costs for projects that exist as of January 1, 2008, or were expected to occur within the next 20 years (2028). Users submitted documentation of needs in the form of engineer estimates, etc. When costs were unavailable, the 2008 CWNS cost curves could be used. The cost models provide costs in January 2008 dollars. Project costs provided in the survey were adjusted to reflect January 2008 dollars. Projects were limited to wastewater system needs eligible for the Clean Water State Revolving Fund (CWSRF) loan program. Information was solicited from all wastewater facilities. Wastewater infrastructure needs are presented for the total state with additional information provided for small communities needs. CWNS defines small communities as those serving 10,000 or less people.

The OCWP method is similar to EPA's 2008 CWNS approach with a few key differences. The 13 OCWP Watershed Planning Regions were the basis for developing the OCWP cost estimates.

A few of the key similarities between the OCWP and 2008 CWNS methodologies include the following:

- The OCWP study used the same classification for infrastructure type: Category 1 includes secondary wastewater treatment, Category II includes advanced wastewater treatment, Category III is for existing collection systems, Category IV includes new collection systems, Category VI includes stormwater management, and Category VII includes nonpoint source pollution control. (Generally, the definitions of each category are the same between the 2008 CWNS and OWRB method; however, costs were not developed for EPA Category V, X, and XII because Oklahoma does not have these types of systems or they are not consistent with the public utilities included in the OWRB study.)
- The OCWP study used the same general definitions of collection systems.
- The OCWP study used the same definition of project costs.
- The OCWP study used the same 2008 CWNS cost models except when EPA cost models were unavailable or did not appear to apply on the more local scale.

A few of the key differences between the OCWP and 2008 CWNS methodologies are listed below:

- For the OCWP study, system sizes were broken down by large (serving more than 100,000 people), medium (between 3,301 and 100,000 people) and small (3,300 or fewer people). Categorization of wastewater utilities was based on projected 2060 population and project size was based on projected 2060 total demands including retail, system losses, and sales. This size stratum was used so that wastewater infrastructure needs would be consistent with water infrastructure needs.
- The OCWP used weighting equations to determine regional costs, since information was not available on every wastewater utility provider.

- The OCWP study used a 50-year planning horizon compared to the 20-year planning period for the 2008 CWNS and used 2020, 2040 and 2060 incremental periods to calculate costs.
- The OCWP study used several sources of information including: Oklahoma system specific information available from the 2008 CWNS; information from the OCWP 2011 wastewater utility survey; and regional or utility water studies and master plans to supplement available information.
- The OCWP project lists included wastewater treatment infrastructure items necessary to meet the 2060 projected annual average day flows.

As noted, one of the sources of information that the OCWP used for the study was the OCWP 2011 wastewater utility survey. This survey was sent to 24 wastewater utilities selected by the OWRB to represent a variety of treatment types and size categories. The survey collected information on the utilities' existing treatment and collection system as well as known future projects. Selection of wastewater utilities for modeling was based on availability of data from recent CWSRF loan applications and survey responses. Utilities were selected to represent the three size stratums (small, medium and large) and most of the treatment level categories.

The next cost-modeling step was to develop a project list for each selected utility. To reduce the subjectivity of this step, a list of standard assumptions was developed and used unless better information was available. First, any master plan or known projects identified in the survey were included. Information provided in the 2011 OCWP utility survey and additional information obtained through the Oklahoma Department of Environmental Quality's National Pollutant Discharge Elimination System (NPDES) were used to complete the project development worksheet. The OCWP standard assumptions also supplemented the available information as needed. The worksheet provided a standard method for estimating types of projects needed, project size, and the project date. The intent was not to make detailed project lists, but to provide basic project information that enabled use of the 2008 CWNS cost models. Completed project lists and costs were used to calculate regional and statewide wastewater infrastructure costs.

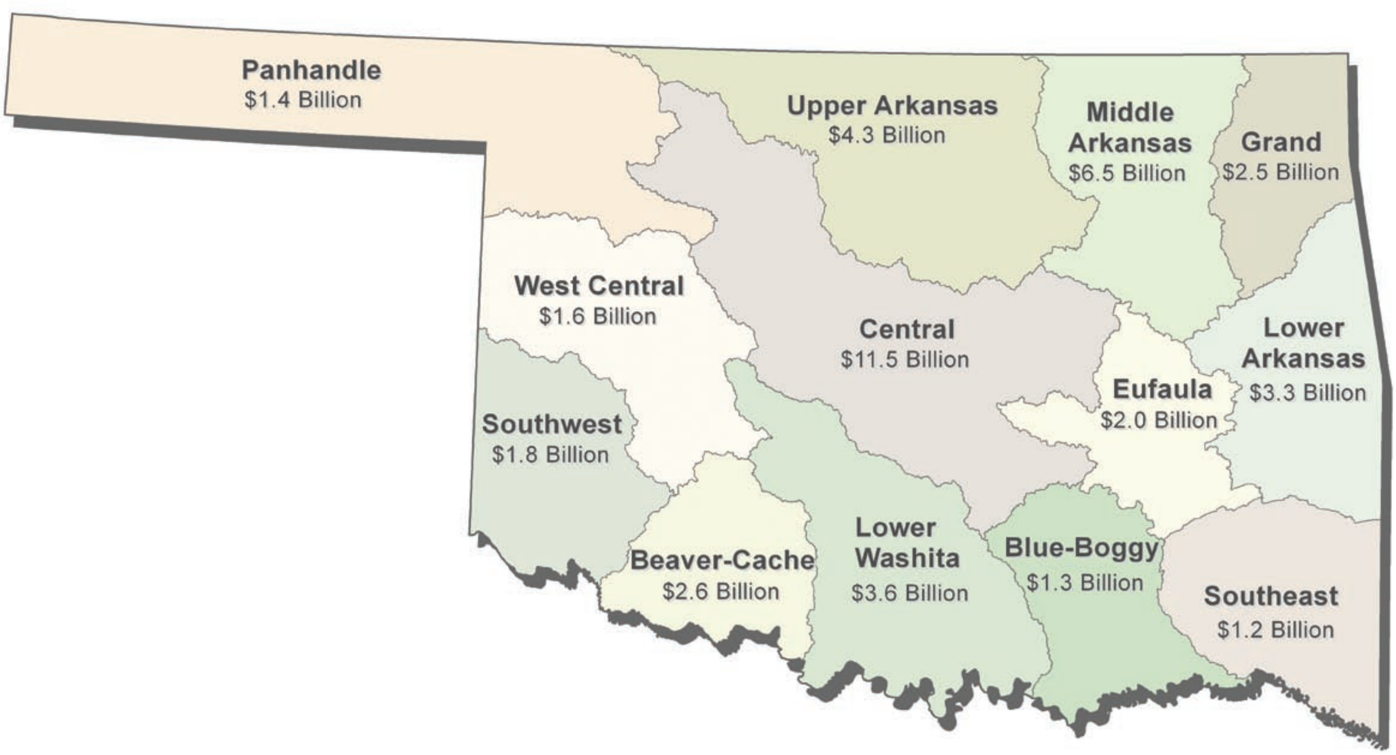
Regional and Statewide Wastewater Cost Estimates

Twenty-two OCWP utilities were selected for cost modeling. The selected utilities' costs were extrapolated using the methodology outlined to calculate the infrastructure costs of the region and state. Across the state, almost $44 billion (in 2010 dollars) is required to meet the wastewater infrastructure needs for the next 50 years.

Costs are not separated into those that are and are not eligible for CWSRF loans because almost all of the projects would be eligible. Medium utilities have the largest overall drinking water infrastructure costs comprising approximately 63% of the state's need. The largest infrastructure costs occur from 2021 through 2040.

To quantify the true costs of these projects over time, an analysis was conducted to factor inflation into the cost

Projected Statewide Wastewater Infrastructure Cost by Region (2010 Dollars)



Wastewater Infrastructure Cost Summary by Region[1]

Region	Present-2020 Infrastructure Need	2021-2040 Infrastructure Need	2041-2060 Infrastructure Need	Total Period Infrastructure Need
	Millions of 2010 dollars			
Beaver-Cache	$710	$1,300	$600	$2,610
Blue-Boggy	$400	$650	$220	$1,270
Central	$3,300	$5,900	$2,300	$11,500
Eufaula	$520	$1,100	$420	$2,040
Grand	$720	$1,300	$480	$2,500
Lower Arkansas	$880	$1,800	$640	$3,320
Lower Washita	$960	$2,000	$630	$3,590
Middle Arkansas	$2,100	$3,100	$1,300	$6,500
Panhandle	$500	$690	$240	$1,430
Southeast	$280	$650	$240	$1,170
Southwest	$480	$1,000	$320	$1,800
Upper Arkansas	$1,140	$2,400	$740	$4,280
West Central	$520	$790	$300	$1,610
Total	**$12,510**	**$22,680**	**$8,430**	**$43,620**

Source: Draft Wastewater Needs Assessment by Region, CDM, November 2011

1 Small differences in values may result from rounding

Statewide Wastewater Infrastructure Cost Summary by Category[1]

Category[1]	Official Needs Category Group	Present-2020 Infrastructure Need	2021-2040 Infrastructure Need	2041-2060 Infrastructure Need	Total Period Infrastructure Need
		Millions of 2010 dollars			
Small	I and II	$170	$1,300	$530	$2,000
	III and IV	$2,200	$4,800	$1,100	$8,100
Medium	I and II	$1,100	$4,000	$1,100	$6,200
	III and IV	$7,500	$10,000	$4,000	$21,500
Large	I and II	$310	$1,000	$830	$2,140
	III and IV	$900	$1,600	$780	$3,280
Regional	VI	$240	$0	$0	$240
	VII	$170	$130	$130	$430
Total		**$12,590**	**$22,830**	**$8,470**	**$43,890**

Source: Draft Wastewater Needs Assessment by Region, CDM, November 2011

1 Small differences in values may result from rounding estimates. A rate of inflation of 2.98% was calculated based on the average U.S. Consumer Price Index for the past 15 years, plus 50 basis points. The approximately $44 billion in infrastructure costs increases to almost $83 billion when an inflation factor of 2.98% is applied. This difference is a result of the 50-year planning horizon and compounding effect of the inflation rate during that period.

Inflation Adjusted Wastewater Infrastructure Need

	Present-2020	2021-2040	2041-2060	Total Period
	Millions of 2010 dollars			
Total Period Costs	$12,590	$22,830	$8,470	$43,890
Cost Inflation Adjusted	$14,420	$41,060	$27,410	$82,890

Glossary

Acre-foot: volume of water that would cover one acre of land to a depth of one foot; equivalent to 43,560 cubic feet or 325,851 gallons.

Alkalinity: measurement of the water's ability to neutralize acids. High alkalinity usually indicates the presence of carbonate, bicarbonates, or hydroxides. Waters that have high alkalinity values are often considered undesirable because of excessive hardness and high concentrations of sodium salts. Waters with low alkalinity have little capacity to buffer acidic inputs and are susceptible to acidification (low pH).

Alluvial aquifer: aquifer with porous media consisting of loose, unconsolidated sediments deposited by fluvial (river) or aeolian (wind) processes, typical of river beds, floodplains, dunes, and terraces.

Alluvial groundwater: water found in an alluvial aquifer.

Alluvium: sediments of clay, silt, gravel, or other unconsolidated material deposited over time by a flowing stream on its floodplain or delta; frequently associated with higher-lying terrace deposits of groundwater.

Appendix B areas: waters of the state into which discharges may be limited and that are located within the boundaries of areas listed in Appendix B of OWRB rules Chapter 45 on Oklahoma's Water Quality Standards (OWQS); including but not limited to National and State parks, forests, wilderness areas, wildlife management areas, and wildlife refuges. Appendix B may include areas inhabited by federally listed threatened or endangered species and other appropriate areas.

Appropriative right: right acquired under the procedure provided by law to take a specific quantity of water by direct diversion from a stream, an impoundment thereon, or a playa lake, and to apply such water to a specific beneficial use or uses.

Aquifer: geologic unit or formation that contains sufficient saturated, permeable material to yield economically significant quantities of water to wells and springs.

Artificial recharge: any man-made process specifically designed for the primary purpose of increasing the amount of water entering into an aquifer.

Attainable uses: best uses achievable for a particular waterbody given water of adequate quality.

Background: ambient condition upstream or upgradient from a facility, practice, or activity that has not been affected by that facility, practice or activity.

Basin: see Surface water basin.

Basin outlet: the furthest downstream geographic point in an OCWP planning basin.

Bedrock aquifer: aquifer with porous media consisting of lithified (semi-consolidated or consolidated) sediments, such as limestone, sandstone, siltstone, or fractured crystalline rock.

Bedrock groundwater: water found in a bedrock aquifer.

Beneficial use: (1) The use of stream or groundwater when reasonable intelligence and diligence are exercised in its application for a lawful purpose and as is economically necessary for that purpose. Beneficial uses include but are not limited to municipal, industrial, agricultural, irrigation, recreation, fish and wildlife, etc., as defined in OWRB rules Chapter 20 on stream water use and Chapter 30 on groundwater use. (2) A classification in OWQS of the waters of the State, according to their best uses in the interest of the public set forth in OWRB rules Chapter 45 on OWQS.

Board: Oklahoma Water Resources Board.

Chlorophyll-a: primary photosynthetic plant pigment used in water quality analysis as a measure of algae growth.

Conductivity: a measure of the ability of water to pass electrical current. High specific conductance indicates high concentrations of dissolved solids.

Conjunctive management: water management approach that takes into account the interactions between groundwaters and surface waters and how those interactions may affect water availability.

Conservation: protection from loss and waste. Conservation of water may mean to save or store water for later use or to use water more efficiently.

Conservation pool: reservoir storage of water for the project's authorized purpose other than flood control.

Consumptive use: a use of water that diverts it from a water supply.

Cultural eutrophication: condition occurring in lakes and streams whereby normal processes of eutrophication are accelerated by human activities.

CWSRF: see State Revolving Fund (SRF).

Dam: any artificial barrier, together with appurtenant works, which does or may impound or divert water.

Degradation: any condition caused by the activities of humans resulting in the prolonged impairment of any constituent of an aquatic environment.

Demand: amount of water required to meet the needs of people, communities, industry, agriculture, and other users.

Demand forecast: estimate of expected water demands for a given planning horizon.

Demand management: adjusting use of water through temporary or permanent conservation measures to meet the water needs of a basin or region.

Demand sectors: distinct consumptive users of the state's waters. For OCWP analysis, seven demand sectors were identified: thermoelectric power, self-supplied residential, self-supplied industrial, oil and gas, municipal and industrial, livestock, and crop irrigation.

Dependable yield: the maximum amount of water a reservoir can dependably supply from storage during a drought of record.

Depletion: a condition that occurs when the amount of existing and future demand for groundwater exceeds available recharge.

Dissolved oxygen: amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water. Low levels of dissolved oxygen facilitate the release of nutrients from sediments.

Diversion: to take water from a stream or waterbody into a pipe, canal, or other conduit, either by pumping or gravity flow.

Domestic use: in relation to OWRB permitting, the use of water by a natural individual or by a family or household for household purposes, for farm and domestic animals up to the normal grazing capacity of the land whether or not the animals are actually owned by such natural individual or family, and for the irrigation of land not exceeding a total of three acres in area for the growing of gardens, orchards, and lawns. Domestic use also includes: (1) the use of water for agriculture purposes by natural individuals, (2) use of water for fire protection, and (3) use of water by non-household entities for drinking water purposes, restroom use, and the watering of lawns, provided that the amount of water used for any such purposes does not exceed five acre-feet per year.

Drainage area: total area above the discharge point drained by a receiving stream.

DWSRF: see State Revolving Fund (SRF).

Drought management: short-term measures to conserve water to sustain a basin's or region's needs during times of below normal rainfall.

Ecoregion (ecological region): an ecologically and geographically defined area; sometimes referred to as a bioregion.

Effluent: any fluid emitted by a source to a stream, reservoir, or basin, including a partially or completely treated waste fluid that is produced by and flows out of an industrial or wastewater treatment plant or sewer.

Elevation: elevation in feet in relation to mean sea level (MSL).

Equal proportionate share (EPS): portion of the maximum annual yield of water from a groundwater basin that is allocated to each acre of land overlying the basin or subbasin.

Eutrophic: a water quality characterization, or "trophic status," that indicates abundant nutrients and high rates of productivity in a lake, frequently resulting in oxygen depletion below the surface.

Eutrophication: the process whereby the condition of a waterbody changes from one of low biologic productivity and clear water to one of high productivity and water made turbid by the accelerated growth of algae.

Flood control pool: reservoir storage of excess runoff above the conservation pool storage capacity that is discharged at a regulated rate to reduce potential downstream flood damage.

Floodplain: the land adjacent to a body of water which has been or may be covered by flooding, including, but not limited to, the one-hundred year flood (the flood expected to be equaled or exceeded every 100 years on average).

Fresh water: water that has less than five thousand (5,000) parts per million total dissolved solids.

Gap: an anticipated shortage in supply of surface water due to a deficiency of physical water supply or the inability or failure to obtain necessary water rights.

Groundwater: fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut bank of a definite stream.

Groundwater basin: a distinct underground body of water overlain by contiguous land having substantially the same geological and hydrological characteristics and yield capabilities. The area boundaries of a major or minor basin can be determined by political boundaries, geological, hydrological, or other reasonable physical boundaries.

Groundwater recharge: see Recharge.

Hardness: a measure of the mineral content of water. Water containing high concentrations (usually greater than 60 ppm) of iron, calcium, magnesium, and hydrogen ions is usually considered "hard water."

High Quality Waters (HQW): a designation in the OWQS referring to waters that exhibit water quality exceeding levels necessary to support the propagation of fishes, shellfishes, wildlife, and recreation in and on the water. This designation prohibits any new point source discharge or additional load or increased concentration of specified pollutants.

Hydraulic conductivity: the capacity of rock to transmit groundwater under pressure.

Hydrologic unit code: a numerical designation utilized by the United States Geologic Survey and other federal and state agencies as a way of identifying all drainage basins in the U.S.

in a nested arrangement from largest to smallest, consisting of a multi-digit code that identifies each of the levels of classification within two-digit fields.

Hypereutrophic: a surface water quality characterization, or "trophic status," that indicates excessive primary productivity and excessive nutrient levels in a lake.

Impaired water: waterbody in which the quality fails to meet the standards prescribed for its beneficial uses.

Impoundment: body of water, such as a pond or lake, confined by a dam, dike, floodgate, or other barrier established to collect and store water.

Infiltration: the gradual downward flow of water from the surface of the earth into the subsurface.

Instream flow: a quantity of water to be set aside in a stream or river to ensure downstream environmental, social, and economic benefits are met (further defined in the OCWP *Instream Flow Issues & Recommendations* report).

Interbasin transfer: the physical conveyance of water from one basin to another.

Levee: a man-made structure, usually an earthen embankment, designed and constructed to contain, control, or divert the flow of water so as to provide protection from temporary flooding.

Major groundwater basin: a distinct underground body of water overlain by contiguous land and having essentially the same geological and hydrological characteristics and from which groundwater wells yield at least fifty (50) gallons per minute on the average basinwide if from a bedrock aquifer, and at least one hundred fifty (150) gallons per minute on the average basinwide if from an alluvium and terrace aquifer, or as otherwise designated by the OWRB.

Marginal quality water: waters that have been historically unusable due to technological or economic issues associated with diversion, treatment, or conveyance.

Maximum annual yield (MAY): determination by the OWRB of the total amount of fresh groundwater that can be produced from each basin or subbasin allowing a minimum twenty-year life of such basin or subbasin.

Mesotrophic: a surface water quality characterization, or "trophic status," describing those lakes with moderate primary productivity and moderate nutrient levels.

Million gallons per day (mgd): a rate of flow equal to 1.54723 cubic feet per second or 3.0689 acre-feet per day.

Minor groundwater basin: a distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and which is not a major groundwater basin.

Nitrogen limited: in reference to water chemistry, where growth or amount of primary producers (e.g., algae) is restricted in a waterbody due in large part to available nitrogen.

Non-consumptive use: use of water in a manner that does not reduce the amount of supply, such as navigation, hydropower production, protection of habitat for hunting, maintaining water levels for boating recreation, or maintaining flow, level and/or temperature for fishing, swimming, habitat, etc.

Nonpoint source (NPS): a source of pollution without a well-defined point of origin. Nonpoint source pollution is commonly caused by sediment, nutrients, and organic or toxic substances originating from land use activities. It occurs when the rate of material entering a waterbody exceeds its natural level.

Normal pool elevation: the target lake elevation at which a reservoir was designed to impound water to create a dependable water supply; sometimes referred to as the top of the conservation pool.

Normal pool storage: volume of water held in a reservoir when it is at normal pool elevation.

Numerical criteria: concentrations or other quantitative measures of chemical, physical or biological parameters that are assigned to protect the beneficial use of a waterbody.

Numerical standard: the most stringent of the OWQS numerical criteria assigned to the beneficial uses for a given stream.

Nutrient-impaired reservoir: reservoir with a beneficial use or uses impaired by human-induced eutrophication as determined by a Nutrient-Limited Watershed Impairment Study.

Nutrient-Limited Watershed (NLW): watershed of a waterbody with a designated beneficial use that is adversely affected by excess nutrients as determined by a Carlson's Trophic State Index (using chlorophyll-a) of 62 or greater, or is otherwise listed as "NLW" in Appendix A of the OWQS.

Nutrients: elements or compounds essential as raw materials for an organism's growth and development; these include carbon, oxygen, nitrogen, and phosphorus.

Oklahoma Water Quality Standards (OWQS): rules promulgated by the OWRB in Oklahoma Administrative Code Title 785, Chapter 45, which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.

Oligotrophic: a surface water quality characterization, or "trophic status," describing those lakes with low primary productivity and/or low nutrient levels.

Outfall: a point source that contains the effluent being discharged to the receiving water.

Percolation: the movement of water through unsaturated subsurface soil layers, usually continuing downward to the groundwater or water table (distinguished from Seepage).

Permit availability: the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law.

pH: the measurement of the hydrogen-ion concentration in water. A pH below 7 is acidic (the lower the number, the more acidic the water, with a decrease of one full unit representing an increase in acidity of ten times) and a pH above 7 (to a maximum of 14) is basic (the higher the number, the more basic the water). In Oklahoma, fresh waters typically exhibit a pH range from 5.5 in the southeast to almost 9.0 in central areas.

Phosphorus limited: in reference to water chemistry, where growth or amount of primary producers (e.g., algae) is restricted in a waterbody due in large part to the amount of available phosphorus.

Physical water availability: amount of water currently in streams, rivers, lakes, reservoirs, and aquifers; sometimes referred to as "wet water."

Point source: any discernible, confined and discrete conveyance, including any pipe, ditch, channel, tunnel, well, discrete fissure, container, rolling stock or concentrated animal feeding operation from which pollutants are or may be discharged. This term does not include return flows from irrigation agriculture.

Potable: describing water suitable for drinking.

Primary Body Contact Recreation (PBCR): a classification in OWQS of a waterbody's use; involves direct body contact with the water where a possibility of ingestion exists. In these cases, the water shall not contain chemical, physical or biological substances in concentrations that irritate the skin or sense organs or are toxic or cause illness upon ingestion by human beings.

Primary productivity: the production of chemical energy in organic compounds by living organisms. In lakes and streams, this is essentially the lowest denominator of the food chain (phytoplankton) bringing energy into the system via photosynthesis.

Prior groundwater right: comparable to a permit, a right to use groundwater recognized by the OWRB as having been established by compliance with state groundwater laws in effect prior to 1973.

Provider: private or public entity that supplies water to end users or other providers. For OCWP analyses, "public water providers" included approximately 785 non-profit, local governmental municipal or community water systems and rural water districts.

Recharge: the inflow of water to an alluvial or bedrock aquifer.

Reservoir: a surface depression containing water impounded by a dam.

Return water or return flow: the portion of water diverted from a water supply that returns to a watercourse.

Reverse osmosis: a process that removes salts and other substances from water. Pressure is placed on the stronger of two unequal concentrations separated by a semi-permeable membrane; a common method of desalination.

Riparian water right (riparian right): the right of an owner of land adjoining a stream or watercourse to use water from that stream for reasonable purposes.

Riverine: relating to, formed by, or resembling a river (including tributaries), stream, etc.

Salinity: the concentration of salt in water measured in milligrams per liter (mg/L) or parts per million (ppm).

Salt water: any water containing more than five thousand (5,000) parts per million total dissolved solids.

Saturated thickness: thickness below the zone of the water table in which the interstices are filled with groundwater.

Scenic Rivers: streams in "Scenic River" areas designated by the Oklahoma Legislature that possess unique natural scenic beauty, water conservation, fish, wildlife and outdoor recreational values. These areas are listed and described in Title 82 of Oklahoma Statutes, Section 1451.

Sediment: particles transported and deposited by water deriving from rocks, soil, or biological material.

Seepage: the movement of water through saturated material often indicated by the appearance or disappearance of water at the ground surface, as in the loss of water from a reservoir through an earthen dam (distinguished from Percolation).

Sensitive sole source groundwater basin or subbasin: a major groundwater basin or subbasin all or a portion of which has been designated by the U.S. Environmental Protection Agency (EPA) as a "Sole Source Aquifer" and serves as a mechanism to protect drinking water supplies in areas with limited water supply alternatives. It includes any portion of a contiguous aquifer located within five miles of the known areal extent of the surface outcrop of the designated groundwater basin or subbasin.

Sensitive Water Supplies (SWS): designation that applies to public and private water supplies possessing conditions that make them more susceptible to pollution events. This designation restricts point source discharges in the watershed and institutes a 10 µg/L (micrograms per liter) chlorophyll-a criterion to protect against taste and odor problems and reduce water treatment costs.

Soft water: water that contains little to no magnesium or calcium salts.

State Revolving Fund (SRF): fund or program used to provide loans to eligible entities for qualified projects in accordance with Federal law, rules and guidelines administered by the EPA and state. Two separate SRF programs are administered in Oklahoma: the Clean Water SRF is intended to control water pollution and is administered by OWRB; the Drinking Water SRF was created to provide safe drinking water and is administered jointly by the OWRB and ODEQ.

Storm sewer: a sewer specifically designed to control and convey stormwater, surface runoff, and related drainage.

Stream system: drainage area of a watercourse or series of watercourses that converges in a large watercourse with defined boundaries.

Stream water: water in a definite stream that includes water in ponds, lakes, reservoirs, and playa lakes.

Streamflow: the rate of water discharged from a source indicated in volume with respect to time.

Surface water: water in streams and waterbodies as well as diffused over the land surface.

Surface water basin: geographic area drained by a single stream system. For OCWP analysis, Oklahoma has been divided into 82 surface water basins (also referenced as "planning basins").

Temporary permit: for groundwater basins or subbasins for which a maximum annual yield has not been determined, temporary permits are granted to users allocating two acre-feet of water per acre of land per year. Temporary permits are for one-year terms that can be revalidated annually by the permittee. When the maximum annual yield and equal proportionate share are approved by the OWRB, all temporary permits overlying the studied basin are converted to regular permits at the new approved allocation amount.

Terrace deposits: fluvial or wind-blown deposits occurring along the margin and above the level of a body of water and representing the former floodplain of a stream or river.

Total dissolved solids (TDS): a measure of the amount of dissolved material in the water column, reported in mg/L, with values in fresh water naturally ranging from 0-1000 mg/L. High concentrations of TDS limit the suitability of water as a drinking and livestock watering source as well as irrigation supply.

Total maximum daily load (TMDL): sum of individual wasteload allocations for point sources, safety reserves, and loads from nonpoint source and natural backgrounds.

Total nitrogen: for water quality analysis, a measure of all forms of nitrogen (organic and inorganic). Excess nitrogen can lead to harmful algae blooms, hypoxia, and declines in wildlife and habitat.

Total phosphorus: for water quality analysis, a measure of all forms of phosphorus, often used as an indicator of eutrophication and excessive productivity.

Transmissivity: measure of how much water can be transmitted horizontally through an aquifer. Transmissivity is the product of hydraulic conductivity of the rock and saturated thickness of the aquifer.

Tributary: stream or other body of water, surface or underground, that contributes to another larger stream or body of water.

Trophic State Index (TSI): one of the most commonly used measurements to compare lake trophic status, based on algal biomass. Carlson's TSI uses chlorophyll-a concentrations to define the level of eutrophication on a scale of 1 to 100, thus indicating the general biological condition of the waterbody.

Trophic status: a lake's trophic state, essentially a measure of its biological productivity. The various trophic status levels (Oligotrophic, Mesotrophic, Eutrophic, and Hypereutrophic) provide a relative measure of overall water quality conditions in a lake.

Turbidity: a combination of suspended and colloidal materials (e.g., silt, clay, or plankton) that reduce the transmission of light through scattering or absorption. Turbidity values are generally reported in Nephelometric Turbidity Units (NTUs).

Vested stream water right (vested right): comparable to a permit, a right to use stream water recognized by the OWRB as having been established by compliance with state stream water laws in effect prior to 1963.

Waste by depletion: unauthorized use of wells or groundwater; drilling a well, taking, or using fresh groundwater without a permit, except for domestic use; taking more fresh groundwater than is authorized by permit; taking or using fresh groundwater so that the water is lost for beneficial use; transporting fresh groundwater from a well to the place of use in such a manner that there is an excessive loss in transit; allowing fresh groundwater to reach a pervious stratum and be lost into cavernous or otherwise pervious materials encountered in a well; drilling wells and producing fresh groundwater there from except in accordance with well spacing requirements; or using fresh groundwater for air conditioning or cooling purposes without providing facilities to aerate and reuse such water.

Waste by pollution: permitting or causing the pollution of a fresh water strata or basin through any act that will permit fresh groundwater polluted by minerals or other waste to filter or intrude into a basin or subbasin, or failure to properly plug abandoned fresh water wells.

Water quality: physical, chemical, and biological characteristics of water that determine diversity, stability, and productivity of the climax biotic community or affect human health.

Water right: right to the use of stream or groundwater for beneficial use reflected by permits or vested rights for stream water or permits or prior rights for groundwater.

Wastewater reuse: treated municipal and industrial wastewater captured and reused commonly for non-potable irrigation and industrial applications to reduce demand upon potable water systems.

Water supply: a body of water, whether static or moving on or under the surface of the ground, or in a man-made reservoir, available for beneficial use on a dependable basis.

Water supply availability: for OCWP analysis, the consideration of whether or not water is available that meets three necessary requirements: physical water is present, the water is of a usable quality, and a water right or permit to use the water has been or can be obtained.

Water supply options: alternatives that a basin or region may implement to meet changing water demands. For OCWP analysis, "primary options" include demand management, use of out-of-basin supplies, reservoir use, increasing reliance on surface water, and increasing reliance on groundwater; "expanded options" include expanding conservation measures, artificial aquifer recharge, use of marginal quality water sources, and potential reservoir development.

Water table: The upper surface of a zone of saturation; the upper surface of the groundwater.

Waterbody: any specified segment or body of waters of the state, including but not limited to an entire stream or lake or a portion thereof.

Watercourse: the channel or area that conveys a flow of water.

Waters of the state: all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state.

Watershed: the boundaries of a drainage area of a watercourse or series of watercourses that diverge above a designated location or diversion point determined by the OWRB.

Well: any type of excavation for the purpose of obtaining groundwater or to monitor or observe conditions under the surface of the earth; does not include oil and gas wells.

Well yield: amount of water that a water supply well can produce (usually in gpm), which generally depends on the geologic formation and well construction.

Wholesale: for purposes of OCWP Public Water Provider analyses, water sold from one public water provider to another.

Withdrawal: water removed from a supply source.

AF: acre-foot or acre-feet

AFD: acre-feet per day

AFY: acre-feet per year

BMPs: best management practices

BOD: biochemical oxygen demand

cfs: cubic feet per second

CWAC: Cool Water Aquatic Community

CWSRF: Clean Water State Revolving Fund

DO: dissolved oxygen

DWSRF: Drinking Water State Revolving Fund

EPS: equal proportionate share

FACT: Funding Agency Coordinating Team

gpm: gallons per minute

HLAC: Habitat Limited Aquatic Community

HQW: High Quality Waters

HUC: hydrologic unit code

M&I: municipal and industrial

MAY: maximum annual yield

mgd: million gallons per day

µS/cm: microsiemens per centimeter (**see specific conductivity**)

mg/L: milligrams per liter

NLW: nutrient-limited watershed

NPS: nonpoint source

NPDES: National Pollutant Discharge Elimination System

NRCS: Natural Resources Conservation Service

NTU: Nephelometric Turbidity Unit (**see "Turbidity"**)

OCWP: Oklahoma Comprehensive Water Plan

ODEQ: Oklahoma Department of Environmental Quality

O&G: Oil and Gas

ORW: Outstanding Resource Water

OWQS: Oklahoma Water Quality Standards

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

pH: hydrogen ion activity

ppm: parts per million

RD: Rural Development

REAP: Rural Economic Action Plan

SBCR: Secondary Body Contact Recreation

SDWIS: Safe Drinking Water Information System

SRF: State Revolving Fund

SSI: Self-Supplied Industrial

SSR: Self-Supplied Residential

SWS: Sensitive Water Supply

TDS: total dissolved solids

TMDL: total maximum daily load

TSI: Trophic State Index

TSS: total suspended solids

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WLA: wasteload allocation

WWAC: Warm Water Aquatic Community

Water Quantity Conversion Factors

Initial Unit \ Desired Unit	CFS	GPM	MGD	AFY	AFD
CFS	—	450	.646	724	1.98
GPM	.00222	—	.00144	1.61	.00442
MGD	1.55	695	—	1120	3.07
AFY	.0014	.62	.00089	—	.00274
AFD	.504	226	.326	365	—

EXAMPLE: Converting from MGD to CFS. To convert from an initial value of 140 MGD to CFS, multiply 140 times 1.55 to come up with the desired conversion, which would be 217 CFS (140 X 1.55 = 217).

CFS: cubic feet per second
GPM: gallons per minute
MGD: millions gallons per day
AFY: acre-feet per year
AFD: acre-feet per day
1 acre-foot: 325,851 gallons

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Crop Irrigation Water Demand (1 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
Adair	1,062	1,290	1,518	1,746	1,922	2,203
Alfalfa	5,043	5,492	5,940	6,389	6,733	7,285
Atoka	1,217	1,441	1,666	1,890	2,063	2,339
Beaver	32,642	33,590	34,538	35,486	36,214	37,383
Beckham	8,718	8,718	8,718	8,718	8,718	8,718
Blaine	6,517	6,517	6,517	6,517	6,517	6,517
Bryan	17,108	17,322	17,536	17,750	17,915	18,178
Caddo	31,644	34,361	37,078	39,794	41,879	45,228
Canadian	6,376	6,597	6,818	7,040	7,210	7,482
Carter	2,742	2,777	2,812	2,847	2,874	2,918
Cherokee	1,501	1,573	1,644	1,716	1,770	1,859
Choctaw	859	1,007	1,154	1,302	1,415	1,597
Cimarron	62,125	67,821	73,517	79,214	83,585	90,606
Cleveland	1,166	1,369	1,571	1,773	1,929	2,178
Coal	637	640	643	645	647	650
Comanche	2,690	2,890	3,089	3,289	3,442	3,688
Cotton	581	687	793	898	980	1,110
Craig	147	638	1,128	1,618	1,995	2,599
Creek	349	391	433	475	508	560
Custer	4,774	4,865	4,957	5,048	5,119	5,232
Delaware	949	949	949	949	949	949
Dewey	4,752	4,752	4,752	4,752	4,752	4,752
Ellis	22,940	25,405	27,870	30,334	32,225	35,263
Garfield	6,029	6,029	6,029	6,029	6,029	6,029
Garvin	1,340	1,819	2,298	2,777	3,144	3,734
Grady	11,291	11,291	11,291	11,291	11,291	11,291
Grant	1,801	1,801	1,801	1,801	1,801	1,801
Greer	6,064	8,255	10,445	12,636	14,317	17,016
Harmon	26,455	27,191	27,927	28,664	29,229	30,137
Harper	10,391	11,075	11,759	12,444	12,969	13,813
Haskell	2,589	2,798	3,006	3,215	3,375	3,633
Hughes	3,285	4,323	5,360	6,398	7,195	8,474
Jackson	101,716	103,765	105,813	107,862	109,434	111,960
Jefferson	363	395	427	459	484	523
Johnston	1,464	1,904	2,344	2,783	3,121	3,662
Kay	4,690	4,690	4,690	4,690	4,690	4,690
Kingfisher	7,926	8,321	8,716	9,111	9,415	9,902
Kiowa	4,563	4,688	4,813	4,939	5,035	5,190
Latimer	848	1,347	1,846	2,346	2,729	3,344

Crop Irrigation Water Demand (2 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
LeFlore	9,985	9,985	9,985	9,985	9,985	9,985
Lincoln	3,575	3,575	3,575	3,575	3,575	3,575
Logan	1,991	1,991	1,991	1,991	1,991	1,991
Love	2,737	3,216	3,695	4,174	4,542	5,133
Major	13,033	13,078	13,122	13,166	13,200	13,254
Marshall	4,655	4,804	4,952	5,100	5,214	5,397
Mayes	1,196	1,303	1,411	1,519	1,602	1,735
McClain	2,868	2,918	2,969	3,019	3,058	3,120
McCurtain	856	1,306	1,756	2,205	2,550	3,105
McIntosh	682	684	685	687	688	690
Murray	43	188	332	476	587	765
Muskogee	8,882	8,882	8,882	8,882	8,882	8,882
Noble	1,223	1,223	1,223	1,223	1,223	1,223
Nowata	261	438	616	793	929	1,148
Okfuskee	1,887	2,077	2,267	2,457	2,602	2,836
Oklahoma	5,537	5,537	5,537	5,537	5,537	5,537
Okmulgee	1,250	1,250	1,250	1,250	1,250	1,250
Osage	538	691	843	996	1,113	1,302
Ottawa	467	533	598	664	714	795
Pawnee	87	133	179	225	260	317
Payne	1,333	1,339	1,344	1,349	1,353	1,360
Pittsburg	2,859	3,079	3,299	3,519	3,687	3,958
Pontotoc	1,702	2,493	3,284	4,075	4,682	5,657
Pottawatomie	1,980	2,309	2,639	2,969	3,222	3,628
Pushmataha	816	820	824	828	831	836
Roger Mills	9,266	9,281	9,296	9,312	9,323	9,342
Rogers	1,509	1,639	1,769	1,900	1,999	2,160
Seminole	1,328	1,587	1,847	2,106	2,305	2,624
Sequoyah	2,221	2,343	2,465	2,587	2,681	2,832
Stephens	2,231	2,898	3,564	4,231	4,742	5,564
Texas	199,713	201,049	202,385	203,721	204,747	206,393
Tillman	18,163	18,412	18,661	18,910	19,101	19,408
Tulsa	7,503	7,757	8,012	8,266	8,461	8,775
Wagoner	8,392	8,392	8,392	8,392	8,392	8,392
Washington	574	721	867	1,014	1,126	1,306
Washita	5,130	5,350	5,571	5,792	5,962	6,234
Woods	3,353	3,570	3,787	4,005	4,171	4,439
Woodward	8,026	8,026	8,026	8,026	8,026	8,026

Livestock Water Demand (1 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
Adair	1,441	1,476	1,511	1,546	1,581	1,616
Alfalfa	1,287	1,325	1,363	1,402	1,440	1,478
Atoka	1,116	1,117	1,117	1,117	1,118	1,118
Beaver	3,067	3,120	3,172	3,224	3,276	3,328
Beckham	770	795	820	846	871	897
Blaine	1,565	1,564	1,562	1,560	1,558	1,557
Bryan	1,564	1,567	1,571	1,575	1,579	1,582
Caddo	2,281	2,281	2,281	2,281	2,281	2,282
Canadian	1,510	1,525	1,541	1,556	1,571	1,586
Carter	779	797	814	832	849	867
Cherokee	829	830	830	831	832	833
Choctaw	1,010	1,012	1,013	1,015	1,016	1,018
Cimarron	1,907	1,940	1,974	2,008	2,041	2,075
Cleveland	421	433	444	456	467	479
Coal	596	619	642	665	688	711
Comanche	1,008	1,029	1,049	1,070	1,090	1,111
Cotton	942	950	957	965	972	979
Craig	1,684	1,689	1,694	1,699	1,703	1,708
Creek	654	668	683	697	712	726
Custer	1,254	1,294	1,335	1,375	1,415	1,455
Delaware	2,310	2,368	2,425	2,483	2,540	2,598
Dewey	713	742	771	800	828	857
Ellis	1,381	1,393	1,405	1,417	1,429	1,441
Garfield	1,361	1,368	1,375	1,383	1,390	1,397
Garvin	1,197	1,203	1,209	1,216	1,222	1,228
Grady	2,181	2,259	2,336	2,413	2,491	2,568
Grant	689	720	751	782	813	843
Greer	442	442	443	443	444	444
Harmon	565	577	589	602	614	626
Harper	1,441	1,448	1,456	1,463	1,470	1,478
Haskell	1,167	1,179	1,191	1,203	1,215	1,227
Hughes	1,654	1,673	1,691	1,709	1,727	1,745
Jackson	592	646	701	755	809	864
Jefferson	1,297	1,301	1,305	1,310	1,314	1,318
Johnston	622	631	640	649	658	667
Kay	618	635	652	670	687	705
Kingfisher	2,198	2,215	2,231	2,248	2,265	2,282
Kiowa	1,082	1,092	1,101	1,110	1,119	1,129
Latimer	571	576	580	584	588	593

Livestock Water Demand (2 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
LeFlore	2,499	2,517	2,535	2,553	2,571	2,588
Lincoln	1,118	1,119	1,121	1,122	1,124	1,125
Logan	742	789	837	884	931	978
Love	655	655	655	655	655	655
Major	1,972	1,998	2,024	2,051	2,077	2,104
Marshall	318	332	347	362	377	392
Mayes	1,322	1,327	1,332	1,337	1,342	1,347
McClain	884	888	892	895	899	903
McCurtain	2,050	2,118	2,187	2,256	2,325	2,394
McIntosh	844	868	892	916	939	963
Murray	401	431	461	491	521	552
Muskogee	1,139	1,146	1,152	1,159	1,166	1,172
Noble	874	876	879	881	883	885
Nowata	1,109	1,108	1,107	1,106	1,105	1,104
Okfuskee	728	736	744	752	760	768
Oklahoma	371	374	377	380	383	386
Okmulgee	744	747	750	753	756	759
Osage	2,323	2,343	2,363	2,384	2,404	2,424
Ottawa	1,055	1,071	1,086	1,102	1,118	1,133
Pawnee	616	617	618	620	621	622
Payne	831	839	848	856	865	874
Pittsburg	1,181	1,194	1,208	1,221	1,235	1,248
Pontotoc	853	870	886	903	919	936
Pottawatomie	947	950	954	957	960	964
Pushmataha	495	502	510	518	525	533
Roger Mills	871	896	921	946	971	996
Rogers	1,119	1,127	1,134	1,142	1,150	1,158
Seminole	627	642	656	671	686	700
Sequoyah	730	758	787	816	845	873
Stephens	1,019	1,044	1,068	1,093	1,117	1,142
Texas	9,161	9,254	9,347	9,440	9,533	9,626
Tillman	889	895	900	905	911	916
Tulsa	338	341	345	349	352	356
Wagoner	640	642	645	647	649	652
Washington	536	539	541	544	547	550
Washita	1,511	1,510	1,510	1,510	1,509	1,509
Woods	1,347	1,374	1,401	1,428	1,455	1,482
Woodward	1,856	1,856	1,857	1,857	1,858	1,858

M&I Water Demand Including System Losses (1 of 2)

Sum of Public Supply Residential & Public Supply Nonresidential

County	2010	2020	2030	2040	2050	2060
	AFY					
Adair	1,994	2,237	2,555	2,874	3,200	3,526
Alfalfa	873	882	882	882	897	912
Atoka	3,024	3,366	3,733	4,101	4,507	4,913
Beaver	714	740	752	765	777	789
Beckham	4,739	5,120	5,562	6,003	6,444	6,930
Blaine	2,474	2,683	2,918	3,153	3,388	3,642
Bryan	8,145	8,942	9,799	10,655	11,511	12,388
Caddo	3,305	3,470	3,578	3,686	3,794	3,892
Canadian	15,448	16,833	18,000	19,008	19,938	20,884
Carter	9,008	9,535	10,048	10,541	11,073	11,643
Cherokee	6,884	7,767	8,760	9,766	10,745	11,751
Choctaw	1,560	1,637	1,667	1,708	1,749	1,790
Cimarron	645	685	705	705	726	746
Cleveland	37,683	40,538	42,804	44,614	45,886	47,126
Coal	626	711	805	908	1,020	1,132
Comanche	16,682	17,839	18,717	19,400	19,937	20,376
Cotton	783	809	821	833	857	869
Craig	2,294	2,507	2,739	3,000	3,260	3,534
Creek	8,399	8,939	9,391	9,821	10,250	10,715
Custer	5,339	5,619	5,852	6,084	6,259	6,414
Delaware	4,223	4,781	5,384	6,007	6,678	7,377
Dewey	1,154	1,146	1,146	1,146	1,171	1,197
Ellis	736	730	730	711	711	730
Garfield	12,248	12,736	13,049	13,341	13,571	13,842
Garvin	4,760	4,926	5,014	5,101	5,206	5,311
Grady	5,188	5,531	5,848	6,133	6,419	6,715
Grant	716	737	752	752	780	794
Greer	1,037	1,049	1,049	1,067	1,085	1,103
Harmon	789	797	821	845	870	894
Harper	961	973	973	973	1,001	1,001
Haskell	1,324	1,466	1,648	1,840	2,032	2,243
Hughes	1,786	1,975	2,178	2,392	2,629	2,866
Jackson	4,619	4,899	5,129	5,314	5,467	5,590
Jefferson	776	795	807	819	843	866
Johnston	1,787	1,969	2,196	2,423	2,666	2,923
Kay	7,711	8,066	8,272	8,463	8,654	8,860
Kingfisher	2,928	3,193	3,529	3,865	4,202	4,575
Kiowa	1,247	1,274	1,287	1,300	1,326	1,351
Latimer	2,260	2,382	2,506	2,651	2,796	2,961

M&I Water Demand Including System Losses (2 of 2)

Sum of Public Supply Residential & Public Supply Nonresidential

County	2010	2020	2030	2040	2050	2060
	AFY					
LeFlore	6,586	7,043	7,499	7,956	8,413	8,895
Lincoln	2,376	2,568	2,745	2,928	3,119	3,322
Logan	4,797	5,354	5,883	6,412	6,929	7,483
Love	1,524	5,138	5,455	5,790	6,144	6,498
Major	984	1,013	1,013	1,027	1,040	1,054
Marshall	2,257	3,634	4,333	5,049	5,800	6,586
Mayes	5,534	6,007	6,526	7,071	7,629	8,200
McClain	4,190	4,792	5,428	6,065	6,726	7,400
McCurtain	4,312	4,527	4,685	4,819	4,965	5,099
McIntosh	2,485	2,760	3,066	3,407	3,793	4,202
Murray	2,712	2,941	3,216	3,471	3,765	4,059
Muskogee	10,130	10,580	10,898	11,172	11,446	11,720
Noble	1,662	1,759	1,815	1,871	1,913	1,955
Nowata	1,118	1,256	1,412	1,568	1,733	1,907
Okfuskee	1,408	1,461	1,497	1,533	1,569	1,616
Oklahoma	123,931	131,224	136,613	140,682	143,644	146,570
Okmulgee	10,930	11,716	12,415	13,141	13,893	14,645
Osage	7,895	8,460	8,876	9,258	9,640	10,073
Ottawa	5,179	5,575	5,918	6,292	6,681	7,069
Pawnee	2,350	2,588	2,818	3,062	3,318	3,574
Payne	12,688	13,656	14,671	15,670	16,374	17,045
Pittsburg	8,445	8,815	9,150	9,541	9,987	10,471
Pontotoc	6,074	6,376	6,596	6,816	7,019	7,222
Pottawatomie	6,060	6,460	6,848	7,220	7,583	7,963
Pushmataha	1,114	1,237	1,371	1,514	1,674	1,834
Roger Mills	618	626	626	626	626	626
Rogers	13,376	14,813	16,213	17,513	18,846	20,212
Seminole	2,801	2,923	3,002	3,081	3,171	3,261
Sequoyah	7,380	8,143	8,886	9,612	10,356	11,099
Stephens	8,570	8,785	8,866	8,967	9,109	9,291
Texas	3,819	4,599	5,513	6,427	7,342	8,242
Tillman	1,345	1,388	1,418	1,447	1,477	1,521
Tulsa	110,045	116,516	121,517	125,042	127,717	130,319
Wagoner	8,402	9,329	10,137	10,881	11,613	12,383
Washington	11,940	12,364	12,486	12,656	12,827	13,021
Washita	1,103	1,151	1,179	1,197	1,225	1,244
Woods	3,161	3,189	3,224	3,259	3,293	3,363
Woodward	5,718	5,989	6,169	6,288	6,438	6,558

Oil & Gas Drilling Water Demand (1 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
Adair	0	0	0	0	0	0
Alfalfa	218	378	583	833	1,128	1,468
Atoka	610	1,177	836	636	361	12
Beaver	698	975	1,300	1,674	2,096	2,566
Beckham	497	702	945	1,226	1,544	1,900
Blaine	296	405	531	674	834	1,011
Bryan	24	33	43	54	67	82
Caddo	556	783	1,051	1,360	1,711	2,102
Canadian	3,581	6,905	4,908	3,733	2,120	70
Carter	3,291	6,344	4,509	3,430	1,948	64
Cherokee	1	1	1	2	2	3
Choctaw	0	0	0	0	0	0
Cimarron	65	90	117	149	185	224
Cleveland	75	122	182	255	340	437
Coal	1,750	3,375	2,399	1,825	1,036	34
Comanche	53	73	95	121	150	181
Cotton	10	14	18	23	28	34
Craig	30	41	54	68	84	102
Creek	216	295	387	492	608	737
Custer	519	755	1,039	1,371	1,751	2,179
Delaware	0	0	0	0	0	0
Dewey	290	427	593	787	1,011	1,263
Ellis	774	1,511	2,478	3,675	5,103	6,760
Garfield	192	283	393	522	671	838
Garvin	504	710	953	1,233	1,550	1,904
Grady	828	1,178	1,594	2,076	2,623	3,237
Grant	211	338	498	690	915	1,172
Greer	6	8	10	13	16	19
Harmon	3	4	5	6	8	9
Harper	356	547	783	1,064	1,389	1,760
Haskell	1,080	2,223	3,735	5,615	7,864	10,481
Hughes	3,185	6,141	4,365	3,320	1,886	62
Jackson	29	60	100	151	211	280
Jefferson	36	50	65	83	103	125
Johnston	96	220	387	596	846	1,140
Kay	161	220	289	366	453	550
Kingfisher	217	316	436	577	739	921
Kiowa	55	75	99	125	155	188
Latimer	521	770	1,072	1,427	1,836	2,297

Oil & Gas Drilling Water Demand (2 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
LeFlore	969	2,009	3,386	5,100	7,151	9,538
Lincoln	491	904	1,442	2,103	2,888	3,797
Logan	396	694	1,078	1,548	2,103	2,744
Love	43	58	77	97	120	146
Major	635	889	1,187	1,531	1,918	2,351
Marshall	434	836	594	452	257	8
Mayes	25	34	45	57	71	86
McClain	183	270	376	501	644	806
McCurtain	0	1	1	1	1	1
McIntosh	609	1,242	2,079	3,120	4,363	5,810
Murray	36	49	65	82	102	123
Muskogee	82	151	242	354	487	640
Noble	384	551	752	986	1,252	1,552
Nowata	397	543	712	904	1,118	1,356
Okfuskee	252	411	612	854	1,138	1,464
Oklahoma	280	430	615	834	1,089	1,379
Okmulgee	194	285	395	525	674	843
Osage	517	708	928	1,178	1,458	1,767
Ottawa	0	0	0	0	0	0
Pawnee	70	116	174	244	326	420
Payne	238	380	557	770	1,019	1,304
Pittsburg	8,477	16,343	11,617	8,836	5,019	165
Pontotoc	186	275	382	509	654	818
Pottawatomie	320	613	997	1,470	2,034	2,689
Pushmataha	14	19	25	32	39	48
Roger Mills	1,040	1,513	2,081	2,747	3,508	4,366
Rogers	158	262	395	555	744	961
Seminole	437	757	1,167	1,667	2,257	2,938
Sequoyah	57	78	102	129	160	194
Stephens	707	1,017	1,388	1,820	2,313	2,866
Texas	870	1,346	1,935	2,639	3,456	4,387
Tillman	41	75	121	177	243	319
Tulsa	128	211	316	443	592	763
Wagoner	118	201	307	436	588	763
Washington	339	464	609	773	957	1,160
Washita	830	1,569	2,535	3,726	5,143	6,786
Woods	509	717	962	1,244	1,563	1,921
Woodward	609	834	1,093	1,388	1,717	2,081

Self-Supplied Residential Water Demand (1 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
Adair	736	858	980	1,102	1,227	1,353
Alfalfa	115	115	115	115	117	119
Atoka	563	632	702	771	847	923
Beaver	350	355	361	367	373	379
Beckham	321	349	380	410	440	473
Blaine	189	206	224	242	260	280
Bryan	369	407	446	485	524	564
Caddo	1,436	1,496	1,543	1,589	1,636	1,678
Canadian	0	0	0	0	0	0
Carter	22	24	25	26	28	29
Cherokee	774	889	1,002	1,118	1,230	1,345
Choctaw	326	335	341	349	358	366
Cimarron	337	358	369	369	379	390
Cleveland	1,329	1,428	1,508	1,571	1,616	1,660
Coal	153	176	199	224	252	280
Comanche	193	207	217	225	231	236
Cotton	0	0	0	0	0	0
Craig	70	77	84	92	100	109
Creek	544	581	611	639	667	697
Custer	447	468	488	507	522	535
Delaware	998	1,147	1,292	1,441	1,602	1,770
Dewey	263	257	257	257	263	269
Ellis	268	261	261	254	254	261
Garfield	188	193	198	202	206	210
Garvin	469	481	490	498	508	519
Grady	1,202	1,288	1,362	1,429	1,495	1,564
Grant	78	80	81	81	84	86
Greer	0	0	0	0	0	0
Harmon	0	0	0	0	0	0
Harper	267	267	267	267	275	275
Haskell	465	528	593	662	731	807
Hughes	86	96	106	116	128	139
Jackson	112	119	124	129	133	135
Jefferson	12	12	12	12	13	13
Johnston	12	13	15	16	18	20
Kay	186	192	197	202	206	211
Kingfisher	553	618	683	748	813	885
Kiowa	0	0	0	0	0	0
Latimer	192	201	212	224	236	250

Self-Supplied Residential Water Demand (2 of 2)

County	2010	2020	2030	2040	2050	2060
	AFY					
LeFlore	553	596	635	673	712	753
Lincoln	1,393	1,518	1,622	1,731	1,843	1,964
Logan	1,442	1,621	1,781	1,941	2,097	2,265
Love	28	75	79	84	89	94
Major	206	209	209	212	215	217
Marshall	61	75	89	104	119	136
Mayes	0	0	0	0	0	0
McClain	794	927	1,050	1,173	1,301	1,432
McCurtain	703	734	760	782	805	827
McIntosh	0	0	0	0	0	0
Murray	0	0	0	0	0	0
Muskogee	663	686	706	724	742	759
Noble	128	134	138	143	146	149
Nowata	51	58	65	72	80	88
Okfuskee	95	98	100	102	105	108
Oklahoma	1,098	1,151	1,198	1,234	1,260	1,286
Okmulgee	0	0	0	0	0	0
Osage	998	1,069	1,122	1,170	1,218	1,273
Ottawa	698	746	792	842	895	947
Pawnee	609	676	736	800	867	934
Payne	671	722	775	828	865	901
Pittsburg	0	0	0	0	0	0
Pontotoc	572	594	615	635	654	673
Pottawatomie	1,279	1,366	1,449	1,527	1,604	1,684
Pushmataha	89	101	112	123	136	149
Roger Mills	104	104	104	104	104	104
Rogers	601	675	739	798	859	922
Seminole	225	232	238	244	251	258
Sequoyah	104	115	126	136	146	157
Stephens	833	843	851	860	874	892
Texas	365	454	545	635	725	814
Tillman	80	81	83	85	87	89
Tulsa	919	969	1,010	1,040	1,062	1,084
Wagoner	0	0	0	0	0	0
Washington	0	0	0	0	0	0
Washita	144	148	152	154	158	161
Woods	355	355	358	362	366	374
Woodward	732	763	786	801	820	835

Self-Supplied Large Industry Water Demand

County	2010	2020	2030	2040	2050	2060
	AFY					
Beaver	375	393	400	406	413	419
Blaine	311	304	330	357	383	412
Canadian	115	113	121	127	134	140
Carter	63	66	70	73	77	81
Choctaw	95	99	101	104	101	99
Comanche	355	346	363	377	387	396
Custer	23	23	23	24	25	26
Garvin	225	219	223	227	232	236
Jackson	601	586	614	636	654	669
Johnston	1,397	1,359	1,380	1,400	1,440	1,481
Kay	11,340	11,880	12,184	12,465	12,746	13,050
Logan	1,176	1,154	1,268	1,382	1,493	1,612
McCurtain	34,058	33,179	34,339	35,320	36,390	37,371
Muskogee	21,658	21,112	21,746	22,293	22,841	23,388
Oklahoma	244	238	247	255	260	265
Osage	576	562	590	615	640	669
Pottawatomie	639	623	661	697	732	768
Sequoyah	1,708	1,672	1,825	1,974	2,127	2,280
Texas	10,724	10,612	12,722	14,831	16,941	19,018
Woodward	3,097	3,016	3,106	3,167	3,242	3,303

Thermoelectric Power Water Demand (Total Withdrawals)

County	2010	2020	2030	2040	2050	2060
	AFY					
Caddo	5,178	5,776	6,444	7,189	8,020	8,947
Canadian	2,364	2,637	2,942	3,282	3,662	4,085
Choctaw	7,304	8,149	9,091	10,142	11,314	12,623
Comanche	2,566	2,863	3,194	3,563	3,975	4,435
LeFlore	5,885	6,565	7,324	8,171	9,116	10,170
Logan	250	279	312	348	388	433
Mayes	4,491	5,010	5,589	6,236	6,956	7,761
McClain	6,540	7,296	8,139	9,080	10,130	11,301
McCurtain	988	1,103	1,230	1,372	1,531	1,708
Muskogee	103,395	115,348	128,683	143,560	160,157	178,672
Oklahoma	10,051	11,213	12,510	13,956	15,569	17,369
Pawnee	37,872	42,251	47,135	52,584	58,663	65,445
Pittsburg	13,316	14,855	16,572	18,488	20,626	23,010
Rogers	23,669	26,405	29,458	32,863	36,662	40,901
Seminole	17,898	19,967	22,275	24,851	27,723	30,929
Tulsa	13,507	15,069	16,811	18,754	20,922	23,341
Wagoner	4,733	5,280	5,891	6,572	7,332	8,179
Woodward	531	593	661	738	823	918

Thermoelectric Power Water Demand (Consumptive Use)

County	2010	2020	2030	2040	2050	2060
	(AFY)					
Caddo	3,207	3,578	3,991	4,453	4,967	5,542
Canadian	1,464	1,633	1,822	2,033	2,268	2,530
Choctaw	4,524	5,047	5,631	6,281	7,008	7,818
Comanche	1,590	1,773	1,978	2,207	2,462	2,747
LeFlore	3,645	4,066	4,536	5,061	5,646	6,299
Logan	155	173	193	215	240	268
Mayes	2,782	3,103	3,462	3,862	4,309	4,807
McClain	4,051	4,519	5,041	5,624	6,274	7,000
McCurtain	612	683	762	850	948	1,058
Muskogee	64,038	71,441	79,701	88,915	99,194	110,661
Oklahoma	6,225	6,945	7,748	8,644	9,643	10,758
Pawnee	23,456	26,168	29,193	32,568	36,334	40,534
Pittsburg	8,247	9,201	10,264	11,451	12,775	14,251
Rogers	14,659	16,354	18,245	20,354	22,707	25,332
Seminole	11,085	12,367	13,796	15,391	17,171	19,156
Tulsa	8,366	9,333	10,412	11,615	12,958	14,456
Wagoner	2,932	3,270	3,648	4,070	4,541	5,066
Woodward	329	367	410	457	510	569

OWRB

Oklahoma Water Resources Board
3800 N. Classen Boulevard
Oklahoma City, Oklahoma 73118
www.owrb.ok.gov